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Assessment of summer drought in 2015 using different indices in the catchment of Blanice River

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Abstract

The year 2015 was characterized by a very low precipitation totals and long rainless periods all over the Czech Republic as well as other central European countries. This fact has attracted the attention of both the public as well as professional society whose focus was recently put more on floods which are hydrologic extremes with more sound impacts. In this paper, the summer period 2015 is in the focus for the catchment of Blanice River (Central Bohemia Region, South Bohemia Region). It was analyzed from both the meteorological and hydrological point of view. Total area of the catchment is 534 km^2 and is located 50 km southeast of Prague. For the assessment of drought, the data from one hydrological gauging as well as from a number of meteorological stations were used. The time series used for this study are more than 50 years long. Drought indices used for this study and presented in this paper were Standardized Precipitation Index (*SPI*), Streamflow Drought Index (*SDI*) and deficit volumes (*DV*). The analyses of precipitation data carried out for given purpose were supported by GIS application in order to get real precipitation data based on available station data. Drought indexes were calculated on the basis of data for entire period, however the emphasis was put on the data from year 2015. The results of all performed analyses show the significance of the drought event which occurred in summer 2015 with respect to both meteorological and hydrological indices. However, the significance of meteorological drought seems to be higher with respect to the results of analyses carried out. The results also show, that there were even more severe drought episodes in past within the analyzed period.

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1. Introduction

Increased frequency and severity of droughts is one of expected impacts of considered climate change in the region of central Europe [1]. It was confirmed already by the analysis of data for period 1962 -1990 by Hisdal et al. [2] and it is expected that this trend will continue. This will affect both humans as well as environment in different ways. Among others, impacts on agriculture [3] and ecosystems [4] can be mentioned. All the expected impacts are considered as important in the Czech Republic despite the fact that it is a region which is relatively abundant in precipitation in comparison with other regions in Europe. The policy has become oriented on more intensive water management in the landscape which is understand as one of possible measures to mitigate droughts in the Czech Republic. Among others, small water reservoirs are considered as a good option for better management of water in the landscape. It is therefore intended to increase the number of small water reservoirs in the landscape in the Czech Republic which became a part of state environmental policy.

In 2015, the entire area of the Czech Republic was affected by a significant drought event. General preliminary evaluation of this event was described by CHMI [5]. According to this material, the deficits in precipitation started in February 2015 and continued until the middle of August. The average deficit was at that time about 150 mm of cumulative precipitation under usual values. The focus is put on the catchment of Blanice River in this paper. This catchment was already analysed by authors in regard with different issues. These were besides others the frequency analysis of droughts [6] and the analysis of available retention volume in extinct ponds [7]. The catchment is one of the areas which are very vulnerable to drought according to map published by Treml et al. [8]. Thus, the detail research focused on droughts is desirable.

2. Study area and data

2.1. Catchment of Blanice River

The catchment of Blanice River is located in the Czech Republic about 50 km southeast of Prague. The total drainage area of the catchment is 543 km^2. Geographically, it belongs to Bohemian-Moravian Highlands and Central Bohemia Uplands. The main direction of Blanice River goes from the south to the north where it confluences to Sázava River. Morphologically, it is a hilly area with occurrence of steep slopes mainly on sides of river valleys. The catchment is drained by Blanice River with its main tributary Chotýšanka River and many smaller tributaries of these rivers. Land use consists mainly of agricultural land but also the percentage of forests is not negligible. Climatologically, the area is located in moderately warm region according to the standard classification used in the Czech Republic.

2.2. Data

The assessment of drought presented in this study was based on time series of measured discharges at the station Radonice and precipitation data for 13 stations inside the catchment and its surroundings. The discharge data available for this study consisted of daily discharges series having the beginning in 1958.

Even more complicated situation was with precipitation data. In this case, the data were combined from two sources. First, the daily totals were available for two stations inside the catchment covering the period 1961-2012. Second, the hourly totals were available for other 11stations covering the period 2013-2015 with missing data from January to June 2013. All stations with available data used within this study are shown in Fig. 1.

In this study, monthly precipitation totals over the catchment of Blanice River were used. The procedure consisted of calculation of daily or hourly areal precipitation totals over the entire catchment. The maximum possible temporal resolution was kept at this point to avoid loss of information in case of missing data. At each time step, areal precipitation total was calculated using Thiessens polygons derived with respect to available data. This means that Thiessens Hourly precipitation data were then summarized into daily data in order to have consistent series of data for further analyses. Monthly precipitation totals were then calculated by summarizing daily totals.

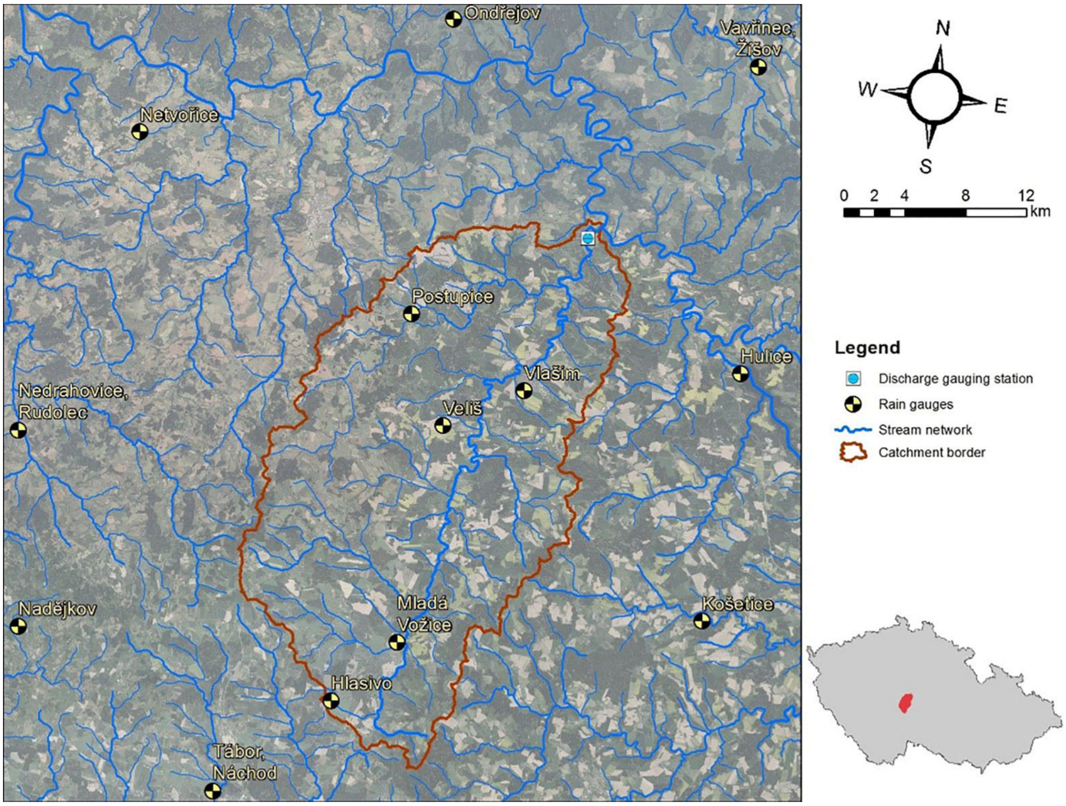

Fig. 1. Map of Blanice River catchment with localization of discharge gauging station and precipitation gauging stations.

3. Methodology

The methodology applied for given purpose followed mainly the standard methods which are used worldwide for the assessment of drought. In this paper, the analysis of both meteorological and hydrological drought indices were calculated and evaluated. In this paper, the application of Standardized Precipitation Index [9] for the assessment of meteorological drought and application of Streamflow Drought Index [10] and deficit volumes calculation for the assessment of hydrological drought is presented.

3.1. Standardized Precipitation Index (SPI)

SPI is an index designed by McKee et al. [9] for the assessment of meteorological drought. This index is applied in many countries for assessment of drought intensity [11,12,13,14]. In principle, the index is based on the comparison of precipitation totals for the period in focus with the long term values. The calculation procedure consists of fitting the data set to the selected probability distribution to get the probability density function, calculating the cumulative probability for each data point and application of inverse normal function with a mean of zero and standard deviation equal to one to this cumulative probability. Originally, Gamma distribution was considered but also other types of distribution have been studied to describe the probability distribution of precipitation [15]. In general, *SPI* can be calculated for the different timescales. In this case, the resulting values of *SPI* for single months are considered only as related to the precipitation totals in respective months (*SPI-1*) and applications with longer time windows are not included in this paper. The limits of drought categories are presented in the Table 1.

Table 1. Drought intensity defined for values of the *SPI*.

SPI value	Drought category
> 0	no drought
0.0 to -0.99	mild drought
-1.0 to -1.49	moderate drought
-1.5 to -1.99	severe drought
< -2	extreme drought

3.2. Streamflow Drought Index (SDI)

SDI is a simple index proposed by Nalbantis and Tsakiris [10] based on the comparison of volumes of streamflow per considered period at respective profile to the long term averages. The index is defined analogically to *SPI* and authors mention that the idea has its origin in Ben-Zvi work [16]. *SDI* was further applied besides others by Tabari et al. [17]. In this case, single months were used as a timescale. The calculation applied for this purpose is described by the Equation 1.

$$SDI_{i,k} = \frac{V_{i,k} - \overline{V}_k}{s_k} \tag{1}$$

In Equation 1, $SDI_{i,k}$ is the value of streamflow drought index for k^{th} month in i^{th} year, $V_{i,k}$ is the volume of streamflow for k^{th} month in i^{th} year, $\overline{V}_k$ is the average value of streamflow volume in k^{th} month over analysed period and s_k is a standard deviation of streamflow volumes in k^{th} month. Drought is assigned to categories using the limits shown in Table 2.

Table 2. Drought intensity defined for values of the *SDI*

SDI value	Drought category
> 0	no drought
0.0 to -0.99	mild drought
-1.0 to -1.49	moderate drought
-1.5 to -1.99	severe drought
< -2	extreme drought

3.3. Deficit volume (DV)

Deficit volume is an index which is different from previous two indices. It is used to express the deficit of discharge over evaluated time period under given threshold value. Then, it can be handled in different ways, e.g. as a subject of further statistical analysis [18, 19, 20]. In this case, single daily discharges (Q) were considered as inputs for which the deficits were calculated and the discharge equal to Q_{355d} was considered as a threshold value [20]. The deficit volumes were calculated as both absolute daily values (DV_d) as well as daily relative values as a percentage of the threshold values (DV_d'). This procedure is described by Equations 2 and 3.

$$DV_d = (Q_{355d} - Q) \cdot 86400 \quad for \quad Q_{355d} \geq Q \tag{2}$$

$$DV_d' = \frac{(Q_{355d} - Q)}{Q_{355d}} \cdot 86400 \quad for \quad Q_{355d} \geq Q \tag{3}$$

Table 3. Values of *SPI* calculated from monthly areal precipitation totals.

SPI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	-1.57	1.00	0.63	0.70	1.11	1.28	-0.65	0.60	-0.50	0.55	-0.45	0.11
1962	0.00	0.57	0.36	0.00	1.59	-1.45	0.30	-0.96	-0.11	-0.96	-0.46	-0.56
1963	-0.07	-0.56	-1.08	-0.38	-0.09	1.45	-2.32	0.04	0.79	-1.16	-0.38	-2.53
1964	-1.47	-0.60	-0.35	0.77	0.34	0.39	-1.47	1.73	-1.34	2.04	-0.28	-0.60
1965	0.37	0.20	0.03	1.79	2.00	0.43	0.85	0.07	-0.48	-1.52	-0.22	1.07
1966	-0.39	0.21	0.42	0.97	-0.16	0.17	1.04	1.84	-1.26	1.12	-0.98	0.89
1967	0.05	-0.13	0.06	-0.51	1.62	-0.12	-0.71	-0.96	1.53	-0.35	-0.27	0.82
1968	0.81	-0.30	-0.80	-0.06	-0.32	-0.44	-0.67	0.32	0.29	0.47	0.15	-0.98
1969	0.08	0.00	0.06	0.09	-0.42	0.01	-1.11	-1.04	-2.57	-1.04	0.57	-0.32
1970	-2.35	1.90	0.41	0.25	-0.39	-0.99	-0.49	0.26	-0.33	0.92	1.59	-0.52
1971	-2.12	0.08	-0.80	-0.11	1.08	1.24	-2.16	-0.04	0.08	-1.37	0.53	-0.33
1972	-1.02	-1.38	-1.37	0.71	0.76	0.75	-0.13	-1.18	1.11	-0.93	-0.71	-3.50
1973	-0.56	-0.10	-0.88	0.30	-0.65	0.32	0.94	-2.28	-1.21	0.04	-0.99	-0.63
1974	0.52	-0.29	-1.50	-1.81	0.24	1.21	0.07	0.21	-0.41	1.86	0.38	2.07
1975	-0.35	-0.29	0.88	-0.44	-0.28	1.13	0.01	-0.19	-1.50	0.00	0.43	-0.92
1976	2.30	-1.05	-0.68	-0.62	-0.71	-0.83	-1.57	-0.32	-0.10	0.93	1.39	-0.57
1977	1.20	0.96	-0.11	0.62	0.43	-0.46	1.10	2.12	-0.26	-0.64	0.10	-0.36
1978	-0.40	-0.97	-0.29	-0.27	0.85	-1.38	-0.51	0.08	1.17	0.02	-0.53	-0.07
1979	0.11	-0.10	1.84	0.44	-1.95	2.30	-0.19	0.02	1.50	-0.87	1.44	0.63
1980	-0.40	0.10	0.08	2.51	-0.88	0.84	1.55	-1.08	-0.12	1.23	-0.24	0.49
1981	0.78	0.68	0.52	-0.06	0.06	-2.05	2.58	-0.87	0.46	1.60	1.00	0.66
1982	0.42	-1.38	0.27	-0.31	-2.18	-0.76	0.47	0.32	-1.38	-0.94	-0.88	0.29
1983	1.52	0.55	-0.55	1.12	0.96	-1.14	-1.45	1.16	-0.55	-1.01	-0.88	-0.99
1984	0.26	0.64	-0.04	0.51	0.81	-1.11	0.01	-1.09	1.19	-0.90	-1.02	-1.40
1985	0.49	0.22	-0.85	-0.13	0.44	0.17	-0.45	0.63	-0.45	-1.48	0.94	-0.09
1986	0.72	-1.61	-0.18	1.00	1.19	-2.02	0.28	0.54	-1.06	-0.02	-1.05	0.92
1987	0.77	1.23	0.02	0.02	0.61	0.11	0.17	-0.27	0.78	-0.74	-0.02	1.14
1988	-0.48	0.87	1.27	-1.41	-0.79	1.62	0.69	-0.06	-0.12	-0.49	0.54	1.15
1989	-1.28	0.46	-0.44	0.81	-1.51	-1.16	0.12	-0.57	1.12	-0.03	-0.59	-1.06
1990	-1.68	1.46	-1.13	1.44	-1.49	-0.49	-2.38	-0.86	0.44	-0.45	1.67	-0.77
1991	-1.67	-1.03	0.02	-0.69	-1.03	0.42	0.24	0.41	-0.94	-1.01	1.87	1.00
1992	0.08	0.73	1.63	-0.46	-3.33	0.34	-0.80	-0.46	-0.80	1.00	0.21	0.56
1993	0.34	0.46	-0.72	-0.46	-0.58	0.79	0.83	-0.04	0.64	0.79	0.78	1.19
1994	-0.17	-0.82	1.21	0.60	-0.59	-1.60	0.11	-0.09	0.38	-0.49	-0.36	1.53
1995	0.77	-0.68	0.39	1.04	1.45	-0.17	-0.92	0.88	1.69	-1.78	0.72	-0.56
1996	-1.54	-1.30	-0.66	-0.09	0.71	1.67	0.70	0.51	0.11	0.44	-0.36	-0.60
1997	-0.94	-0.33	1.27	1.20	-0.86	-0.07	1.34	0.01	-1.67	0.50	0.03	0.91
1998	-1.07	-1.61	0.99	-0.83	-0.23	0.71	0.37	-0.80	1.38	1.68	0.23	-0.97
1999	0.18	1.40	-0.09	-0.71	-0.66	-0.31	0.19	-0.95	0.26	-0.22	-0.83	0.29
2000	0.87	1.29	2.78	-1.76	-0.53	-0.59	0.84	-1.32	-0.46	0.87	-0.95	-0.82
2001	-0.19	-0.50	0.99	1.07	0.85	0.77	0.91	-0.04	1.91	-0.48	0.88	1.81

SPI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	-0.94	1.43	0.26	-1.59	-1.68	0.35	0.23	2.52	0.62	1.63	1.91	0.67
2003	1.18	-1.19	-2.94	-1.24	0.55	-0.44	-0.37	-0.95	-0.34	0.62	-1.45	0.93
2004	1.61	1.10	0.50	0.06	-0.36	0.97	-0.73	-0.65	0.62	-0.42	1.00	-1.48
2005	1.38	2.13	-0.56	-0.62	-0.12	0.16	1.39	0.49	-0.04	-1.98	-1.08	1.13
2006	0.12	0.56	1.39	1.97	1.67	0.95	-1.01	1.22	-1.24	-0.28	0.10	-0.47
2007	0.81	0.69	0.39	-3.42	0.44	0.26	1.06	0.32	1.92	-0.13	1.31	-1.21
2008	-0.26	-0.45	0.35	0.32	-0.70	-0.59	-0.61	-0.13	-1.06	0.72	0.82	-0.49
2009	-0.87	1.38	1.17	-1.23	0.58	0.90	1.00	-0.12	-1.52	1.28	-0.96	1.24
2010	1.38	-1.10	-0.38	0.22	0.93	-0.71	0.56	1.89	1.07	-2.01	0.68	1.04
2011	0.37	-1.14	-0.90	0.08	0.29	0.76	1.57	0.13	-0.20	0.73	-5.39	0.43
2012	1.96	0.64	-1.44	0.34	-0.64	-0.47	1.01	0.41	-0.11	0.58	-0.49	1.38
2013							-0.74	0.24	0.65	0.15	-1.19	-1.72
2014	-0.55	-2.73	-0.29	-0.80	1.49	-2.94	-0.15	0.01	1.21	0.57	-1.92	-0.52
2015	0.34	-2.44	-0.60	-1.51	-0.85	-0.68	-1.39	-0.05	-1.20	0.95	1.51	-0.80

Table 4. Values of *SDI* calculated from monthly streamflow volumes at Radonice.

SDI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	-0.41	2.17	-0.41	-0.01	0.36	1.01	-0.35	-0.04	-0.19	-0.33	-0.48	-0.31
1962	-0.68	-0.49	0.05	0.39	2.28	0.12	-0.36	-0.27	-0.55	-0.39	-0.24	-0.95
1963	-1.14	-1.40	-0.13	-0.62	-0.40	-0.14	-0.39	-0.44	-0.38	-0.50	-0.78	-1.06
1964	-1.12	-0.43	-0.35	-0.58	-0.57	-0.46	-0.75	-0.22	-0.32	1.00	0.56	0.53
1965	0.14	-0.37	2.03	1.87	5.12	3.27	1.53	0.03	0.46	-0.15	-0.03	0.67
1966	0.27	1.53	-0.37	0.25	0.00	-0.26	1.82	2.29	3.87	1.17	1.25	2.36
1967	1.36	1.97	-0.06	-0.08	1.14	0.66	-0.07	-0.23	0.69	-0.16	-0.70	0.80
1968	2.46	0.51	-0.23	-0.64	-0.73	-0.35	-0.93	-0.41	-0.61	-0.23	-0.27	-0.76
1969	-0.73	-0.29	0.13	-0.16	-0.47	-0.44	-0.84	-0.50	-0.79	-0.71	-0.98	-1.10
1970	-1.12	-1.10	1.28	0.70	-0.45	-0.35	-0.89	-0.27	-0.66	-0.13	1.04	-0.08
1971	-0.52	-0.46	-0.53	-0.58	-0.22	0.84	-0.07	-0.39	-0.53	-0.40	-0.57	-0.54
1972	-0.74	-0.74	-0.99	-0.68	0.72	0.25	-0.08	-0.33	-0.42	-0.15	-0.54	-0.78
1973	-0.97	-0.81	-0.94	-0.66	-0.56	-0.42	-0.09	-0.37	-0.82	-0.67	-0.72	-0.69
1974	-0.49	-0.57	-1.12	-1.30	-0.75	-0.18	-0.15	-0.21	-0.34	0.27	1.55	3.97
1975	1.03	-0.41	-0.17	-0.26	-0.40	-0.09	2.26	-0.20	-0.04	-0.31	-0.25	-0.49
1976	2.39	0.11	-0.69	-0.45	-0.40	-0.39	-0.95	-0.46	-0.55	-0.60	0.19	-0.32
1977	0.11	3.06	0.29	-0.43	0.82	0.73	1.75	6.21	2.35	0.46	1.35	0.31
1978	0.17	-0.13	0.00	-0.10	0.93	-0.10	0.13	-0.08	-0.27	0.05	-0.10	0.94
1979	0.99	-0.44	1.76	1.76	-0.01	0.99	1.27	-0.02	1.67	0.96	1.85	1.79
1980	-0.41	-0.71	-1.05	0.97	1.16	-0.20	2.79	0.06	0.09	0.36	-0.31	0.23
1981	0.44	2.30	0.82	-0.76	-0.24	-0.46	2.45	0.07	-0.38	0.33	2.45	1.44
1982	0.43	0.23	-0.01	0.13	0.02	-0.35	-0.18	-0.25	-0.61	-0.55	-0.81	-0.88
1983	-0.43	-0.41	0.14	1.02	-0.45	-0.46	-0.65	-0.05	-0.20	-0.56	-1.05	-0.93
1984	-1.07	-0.57	-1.11	0.33	0.60	-0.33	-0.34	-0.26	-0.06	-0.32	-0.02	-0.62
1985	-1.00	-0.30	-0.45	-0.70	-0.37	-0.22	-0.24	0.07	-0.22	-0.55	-0.73	-0.25

SDI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	0.76	-0.78	-0.91	0.00	0.23	0.07	-0.56	-0.30	-0.47	-0.54	-1.02	-0.58
1987	0.06	1.94	0.35	1.67	0.70	0.46	0.27	-0.22	-0.33	-0.52	-0.28	0.76
1988	-0.22	-0.15	2.24	0.50	-0.69	-0.30	-0.33	-0.29	-0.23	-0.66	-1.08	1.00
1989	-0.05	-0.57	-0.96	-0.84	-0.58	-0.50	-0.81	-0.44	-0.63	-0.48	-0.84	-0.70
1990	-0.64	-0.88	-0.58	-0.76	-0.40	-0.51	-1.00	-0.50	-0.86	-0.87	-0.95	-0.84
1991	-0.91	-1.24	-1.26	-0.93	-0.73	-0.52	-0.76	-0.19	-0.88	-0.72	-0.60	-0.29
1992	0.49	-0.13	-0.04	0.24	-0.66	-0.43	-0.87	-0.50	-0.85	-0.70	-0.88	-0.83
1993	-0.70	-1.08	-0.48	-0.65	-0.82	-0.50	-0.33	-0.35	-0.47	-0.48	0.06	1.34
1994	0.43	0.35	-0.35	-0.23	-0.56	-0.56	-0.95	-0.49	-0.67	-0.64	-0.92	-0.59
1995	1.28	-0.35	-1.13	0.63	1.42	0.32	-0.39	-0.40	1.72	0.56	0.99	0.52
1996	-0.18	-1.00	-0.49	-0.12	1.38	-0.08	1.27	-0.02	-0.02	-0.04	0.31	-0.33
1997	-0.71	0.80	-0.38	0.71	-0.09	-0.40	0.25	-0.20	-0.34	-0.25	-0.65	0.17
1998	-0.81	-1.10	-0.64	-0.92	-0.79	-0.42	-0.63	-0.33	-0.29	-0.16	1.25	-0.32
1999	-0.51	0.48	0.94	-0.87	-0.73	-0.55	-0.72	-0.46	-0.57	-0.61	-0.83	-0.94
2000	-0.07	0.89	1.30	0.51	-0.78	-0.56	-0.67	-0.49	-0.79	-0.55	-0.99	-1.01
2001	-1.07	-1.00	-0.52	0.98	0.37	-0.26	0.40	-0.11	3.13	1.06	0.93	0.80
2002	1.07	1.48	0.12	-0.12	-0.72	-0.49	-0.60	1.77	1.76	2.52	2.97	2.22
2003	2.50	-0.32	-0.29	-0.91	-0.50	-0.33	-0.87	-0.47	-0.75	-0.61	-0.98	-1.02
2004	-0.43	0.73	-0.17	-0.17	-0.61	-0.07	-0.52	-0.44	-0.57	-0.52	0.00	-0.63
2005	-0.33	1.35	1.26	-0.27	-0.68	-0.54	-0.11	0.04	-0.10	-0.36	-0.82	-0.74
2006	-0.81	-0.71	3.89	4.44	1.48	0.78	0.56	-0.04	-0.49	-0.43	-0.66	-0.74
2007	-0.73	0.74	-0.39	-0.86	-0.75	-0.49	-0.65	-0.35	0.56	0.07	2.25	0.73
2008	-0.25	-0.37	-0.30	-0.32	-0.48	-0.41	-0.80	-0.47	-0.80	-0.42	-0.78	-0.85
2009	-0.93	-1.00	1.31	-0.35	-0.59	-0.38	1.06	-0.15	-0.52	-0.20	-0.49	-0.39
2010	-0.35	-0.66	1.20	0.08	0.62	0.45	-0.52	1.52	1.28	0.95	0.15	0.32
2011	3.44	0.49	-0.66	-0.63	-0.61	-0.38	-0.12	-0.10	-0.13	-0.05	-0.58	-0.75
2012	1.11	0.78	-0.23	-0.55	-0.67	-0.45	-0.45	-0.35	-0.30	-0.25	0.21	0.85
2013							0.78	-0.11	0.70	0.60	0.39	-0.30
2014	-0.56	-0.87	-1.12	-1.15	-0.42	-0.53	-0.89	-0.46	0.61	0.45	0.05	-0.53
2015	0.41	-0.62	-1.01	-0.82	-0.69	-0.55	-0.94	-0.47	-0.85	-0.41	-0.26	-0.03

4. Results

The results of calculation procedures applied for this purpose were evaluated in both numerical and graphical way. These results are described individually with respect to indices presented in this paper. Joint evaluation is involved in conclusions of this paper.

4.1. Standardized Precipitation Index (SPI)

First, the precipitation total was calculated for the period from February to June 2015 in order to assess this value with respect to overall situation. The precipitation total for this period was 181 mm. This total is 161 mm less than the long term average being 341 mm. Observed value is the lowest among the whole analysed period. Thus, the period was very dry according to this general assessment because the precipitation was nearly half of long term average. Detail analysis could be then done using values of *SPI*. The lowest values of this index occurred in February and April being -2.44 and -1.51

respectively. Such values are classified as extreme and severe drought respectively according to standard applications of *SPI*. In February which is considered as the beginning of precipitation deficits period, the value of *SPI* is the second lowest among the whole analysed period. Then, it is the fifth lowest in April and the seventh lowest in July. The other values are not that significantly low with respect to the whole period but the importance lies mainly in the fact that negative values were observed in each month from February to Septemeber. From this point of view, it is the second longest sequence of precipitation deficits. The drought in 2015 can be thus considered as significant and as one the most severe events among analysed period with respect to precipitation. The detail values of *SPI* for the whole period are shown in Tables 3 and 4.

4.2. Streamflow Drought Index (SDI)

SDI was used as one of indexes for the assessment of hydrologic drought. In 2015, negative values of this index were identified for the period from February to December. The lowest value in 2015 was observed in March when it was -1.01 which means moderate drought according to usually used classification. Observed value is the seventh lowest value observed in March within studied period. The absolutely lowest value in March within the analysed period (-1.26) was observed in 1991 which was a very dry year together with 1990 and 1992. Moderate drought was not observed in any other month in 2015. Other low values were identified in July, September and April which were -0.94, -0.85 and -0.82 respectively. Absolutely lowest value within the analysed period was observed in February 1963 which was -1.4. All calculated values of *SDI* for a period from 1961 to 2015 are shown in Table 3. The values of *SDI* do not indicate the year 2015 to be one of the driest within analysed period. However, the importance can lie in the total duration of drought which could not be evaluated yet as there were no data available for 2016.

4.3. Deficit volumes (DV)

Values of *DV* were calculated in daily time step on the contrary to the application of *SPI* and *SDI*. This analysis was carried out in order to describe drought in more detail. As a threshold value for the calculation of deficit volumes Q_{355d} = 0.21 $m^3.s^{-1}$ was used which was calculated within previous studies using standard frequency analysis of daily discharge data [6]. First deficits in 2015 occurred in individual days in the first half of July. However, these deficits were very small, having values in units of $l.s^{-1}$. Then, since 22 July 2015 the continuous period with discharges lower than the threshold value started which ended on 15 August 2015 when storm rainfall occurred in the catchment of Blanice River. The maximum deficit which was observer in this period reached the value 0.16 $m^3.s^{-1}$. This corresponds with the relative value of 76.2 % and thus it is very low discharge. After this interruption, another period of discharges under the threshold value started on 26August 2015 and lasted until 10September 2015 with the highest value of discharge deficit 0.12 $m^3.s^{-1}$ representing 55.6 % of the threshold value. Then, the last continuous period of discharges lower than the threshold started on 18 September 2015 and lasted till 6 October2015 with the interruption of one day on 4 October 2015.

The highest observed deficit within the analyzed period occurred on 12 January 1970 when the river became almost dry. The year 2015 was not the driest neither with respect to the duration of drought nor with respect to the total deficit volume. The total deficit volume in 2015 is 522637 m^3 which corresponds with approximately one month of discharge equal to the threshold value. In the driest period within analyzed period (1990-1992), the total deficit volume was $1.79 \cdot 10^6$ m^3 which is a slightly higher value. This means, among others, that the year 2015 was one of the driest with respect to the discharge. The detail overview of deficit discharges within the analyzed period is shown in Fig. 2. As other years with significant duration and total volume of discharge deficits, 1969, 1994, 2000 and 2008 can be mentioned.

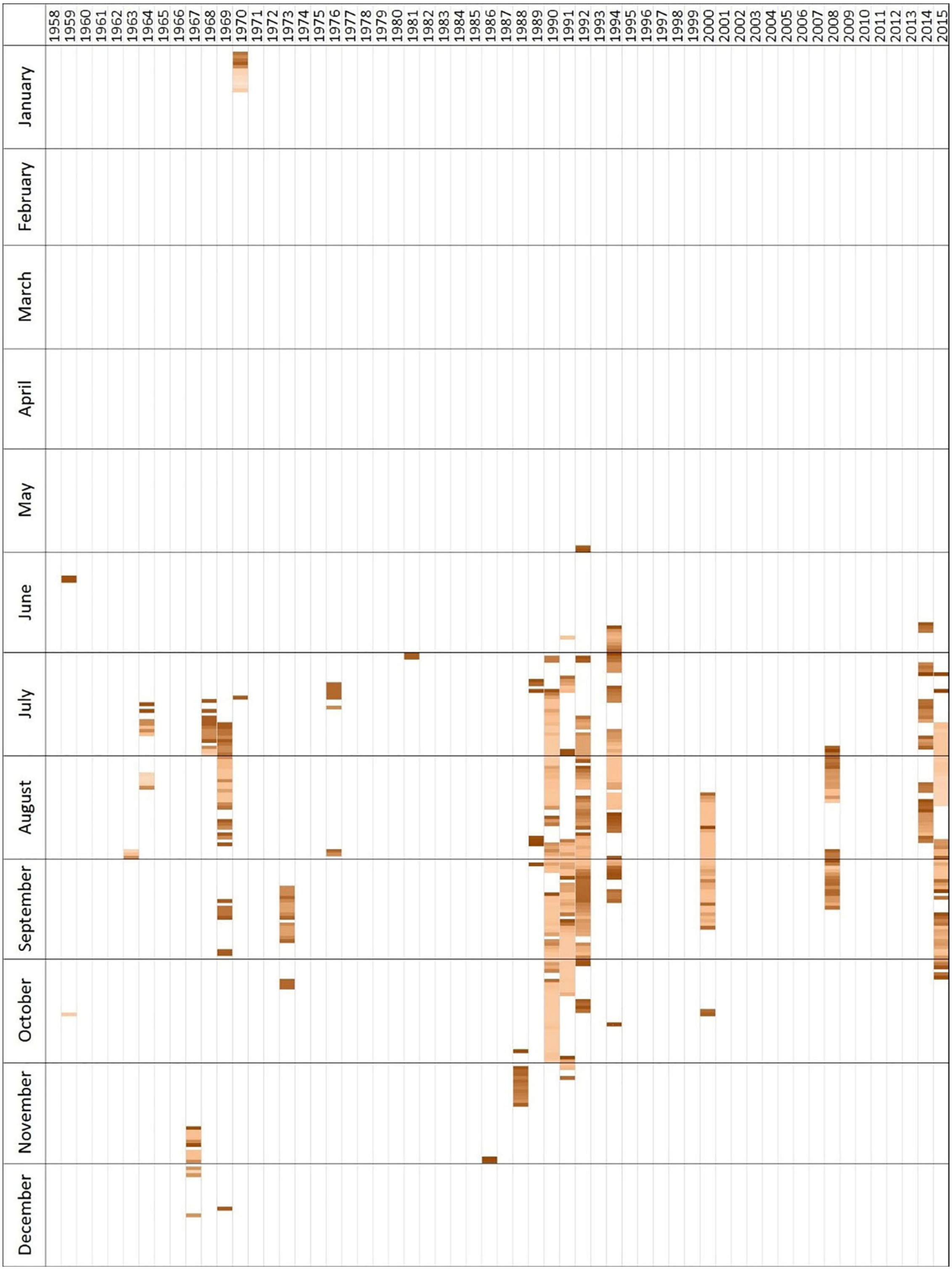

Fig. 2. Deficit volumes plotted with the consideration of Q_{355d} as the threshold value (the darker colour means higher values of deficit volumes).

5. Conclusions

The results of presented analyses confirm that the year 2015 was one of the driest from 1961 to presence mainly with respect to meteorological drought. The comparison of meteorological and hydrological drought indices demonstrates causality of precipitation and runoff which is significant when looking at the value of *SPI* for February and at the value of *SDI* in March. However, this need to be further analyzed in a quantitative way. Obtained results also indicate that the discharge deficits in summer are most likely the result of precipitation deficits in previous period. However, it will be necessary to make analyses over longer time windows with respect to precipitation to demonstrate causality between precipitation deficits, discharge deficits and hydrologic drought. The focus will be also put on the testing of cross correlation between values of meteorological and hydrological drought indices. The importance of hydrologic drought consists also in duration which however could not be evaluated as negative values lasted until the end of the year 2015 (this means at least 11 consecutive months with negative values of *SDI*) and further data were not available for this study. However, it cannot be yet understood as one of most severe hydrologic droughts in comparison to droughts from early sixties and early nineties which lasted for two and three years.

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