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The drought characteristics and their changes in selected water-gauging stations in Slovakia in the period 2001–2020 compared to the reference period 1961–2000

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Reassessing the hydrological characteristics with regard to drought is very important in the context of a changing climate. In this paper, we evaluate the drought in terms of changes in hydrological characteristics for the 20-year period 2001–2020. The evaluation of changes is based on a comparison of data for this period with the currently valid reference period 1961–2000 in 13 selected water-gauging stations. In the analysis of the occurrence of subnormal mean annual discharges (Q_r <90% $Q_{a,1961\text{-}2000}$), in most of the evaluated stations, the percentage incidence of such years is higher in the period 2001–2020 than in the reference period. The distribution of runoff throughout the year in the period 2001–2020 in comparison with the reference period in most stations confirms the changes identified in the previous evaluation of the period 2001–2015, i.e. the transfer of part of the usual increased spring runoff to previous, winter months. An exception was water-gauging stations on streams in the mountainous areas of northern Slovakia, where changes are reflected to a lesser extent.

KEY WORDS: hydrological drought, mean monthly discharge, runoff distribution change

Introduction

Currently, much attention is paid to the issue of climate change and drought. Drought and its increasing occurrence are considered to be the one of the most serious impacts of climate change. The Slovak Hydrometeorological Institute (SHMI) has been dealing for a long time with the assessment of drought from various aspects, also in accordance with the recommendations of the publication Tallaksen and Van Lanen (2004) and the WMO manual (WMO, 2008). The partial results were published also in monographs Fendeková et al. (2010; 2017). SHMÚ also regularly assesses the validity of long-term and design hydrological characteristics as well as the representativeness of the reference period in accordance with national Decree 418/2010 (Decree of the Ministry of Agriculture, Environment and Regional Development of the Slovak Republic on the implementation of certain provisions of the Water Act) §8 point (3). The long-term hydrological characteristics were determined for the currently valid reference period in Slovakia 1961–2000, which we can consider as stable in terms of trends. In next periods, changes in the long-term characteristics were continuously reassessed in view of the possible need to change the reference period. After 15 years, the hydrological characteristics associated with drought, their development and changes in terms of the hydrological regime of surface streams in Slovakia were evaluated in detail. In three partial reports Evaluation of hydrological drought (Poórová et al., 2018; Blaškovičová et al., 2020; Blaškovičová et al., 2021), selected flow and non-flow characteristics of drought in the period 2001–2015 were compared in water-gauging stations with long-term observation against the reference period 1961–2000. In this paper, given that we have data for the next 5 years, we evaluate the drought for selected water-gauging stations in terms of changes in hydrological characteristics for the 20-year period 2001–2020 compared to the reference period. The analyzes serve not only as a basis for evaluating the character of the last 20 years in terms of changes in hydrological characteristics and their regime in time and space, but also the suitability of a representative period is assessed in accordance with Slovakia's Water Plan at least every six years. That is the first step to further re-evaluation of the representative period and possible need for its change.

Data and methods

The evaluation of changes is based on a comparison of data from the period of hydrological years 2001–2020 with the reference period 1961–2000 in 13 selected water-gauging stations (WS) with the representation of different areas of Slovakia (Table 1, Fig. 1). We also

evaluated the Danube River itself in the Bratislava profile, although its regime has a different character due to its size (several times higher than other rivers in Slovakia) and, as its runoff is created mainly outside our territory, it does not even reflect the climatic and runoff conditions of Slovakia. However, it is an important source of water flowing into our territory, also ensuring the replenishment of groundwater in the most important source of drinking water in Slovakia, Žitný ostrov.
In selected WSs we have evaluated:

- mean annual discharges (Q_r) – their evolution in the compared periods,
- long-term mean discharges (Q_a) – changes in the period 2001–2020 compared to the reference period 1961–2000, evaluation of 20-years moving averages in the period 1961–2020,
- changes in long-term mean monthly discharges (Q_{ma}) and changes in the runoff distribution during the year in the compared periods,
- frequencies of occurrence of extremely small monthly flows (Q_m) and their changes in the compared periods,
- changes in the flow duration curves (FDC) – in particular low-flow quantiles (M-day discharges, Q_{Md}),
- non-flow characteristics: the number of days of low-flow periods analyzed, i.e. days with mean daily discharges (Q_d) lower than the selected limits; the values of M-day discharges Q_{364d}, Q_{355d}, Q_{330d} and Q_{270d} for reference period 1961–2000 used as limits.

Table 1. **List of selected water-gauging stations**

Station number	Stream	Station	Catchment area [km^2]	Altitude [m a.s.l.]
5140	Danube	Bratislava	131 331.10	128.43
5100	Močiarka	Láb	47.10	144.33
5160	Blatina	Pezinok	19.09	238.59
6540	Nitra	Nedožery	181.57	287.00
5400	Belá	Podbanské	93.49	922.62
6300	Rajčianka	Poluvsie	243.60	393.03
6450	Vlára	Horné Srnie	341.79	238.00
7015	Hron	Brezno	582.08	490.93
7065	Štiavnička	Mýto p. Ďumbierom	47.10	616.75
7730	Štítnik	Štítnik	129.63	284.95
8870	Torysa	Košické Olšany	1 298.30	185.88
8530	Hnilec	Stratená	68.23	789.24
7930	Javorinka	Ždiar-Podspády	34.89	907.80

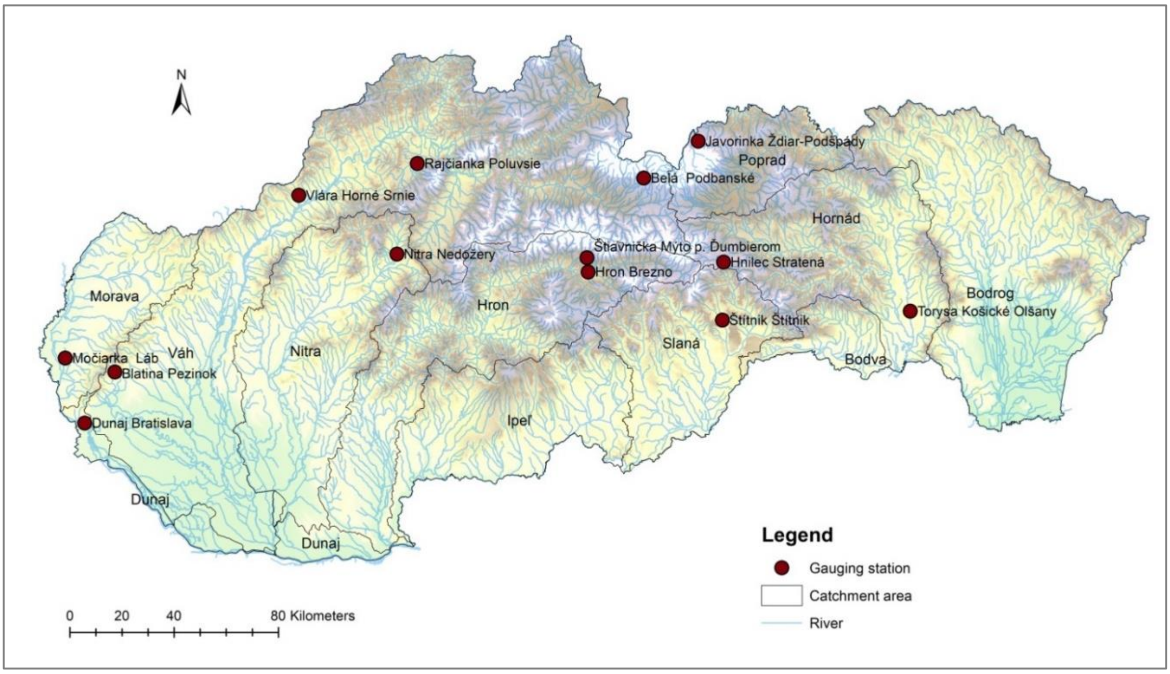


Fig. 1. *Situation of selected water-gauging stations.*

Results and discussion

Mean annual discharges (Q_r) and mean long-term discharges (Q_a): The evaluation of the Q_r series for the period 1961–2020 shows a different evolution in selected stations. In most of the evaluated WSs, the simple linear trend manifests itself as declining. In several profiles, this is mainly due to several significantly above-average Q_r values at the beginning of the evaluated period (in its first 10 years). The exceptions are WSs in the northern part of Slovakia – Podbanské – Belá and Ždiar-Podspády – Javorinka, where the linear trend is growing.

This is also in line with the comparison of Q_a values in the period 2001–2020 against the reference period 1961–2000 (Fig. 2). In most evaluated WSs, the value of $Q_{a,2001-2020}$ is lower compared to the reference period. The more significant decrease (below -10%) was reflected in the WS in the west and south-west of Slovakia: Láb –Močiarka (-32%), Pezinok – Blatina and Nedožery – Nitra (-15%), Poluvsie – Rajčianka (-13%). We recorded a decrease of -7% in WS Mýto p. Ďumbierom – Štiavnička and a slight decrease to -5% in 3 WSs: Štítnik – Štítnik, Košické Olšany – Torysa and Bratislava – Danube. We record a slight increase in $Q_{a,2001-2020}$ compared to the reference period (up to 5%) in only 3 of the evaluated WSs; these are mountain streams in the north and center part of Slovakia – Belá, Javorinka and Hnilec.

For a better assessment of the position of the evaluated 20-year period 2001–2020 in the whole period 1961–2020, we processed the moving averages of Q_a of individual 20-years with a step of 1 year. It is interesting, that the mean long-term discharge in the 20-years 2001–2020 with the value of 1988 $m^3 s^{-1}$ on the Danube River in Bratislava is the lowest in the whole evaluated period (Fig. 3).

Similar results are also in WS Láb – Močiarka, where $Q_{a,2001-2020}$ is also the lowest value among the moving averages of the whole period. The mean values in assessed period 2001–2020 in WSs Nedožery – Nitra, Poluvsie – Rajčianka and Horné Sŕnie – Vlára (Fig. 4) have been the 2. lowest among the moving averages, while the lowest values Q_a have come for previous 20-year period 2000–2019.

The position of $Q_{a,2001-2020}$ values in the rest of WSs range between 14th to 22nd lowest of all 41 moving averages. An exception present the three mountain profiles – WSs on the rivers Belá, Javorinka (Fig. 5) and Hnilec, where the values of $Q_{a,2001-2020}$ were among the 7th to 11th highest values of the whole period.

Identifying the 10 driest years in the series of mean annual discharges of the period 1961–2020, in most evaluated WSs, 4 to 6 years are from the period 2001–2020. Taking into account the lengths of compared periods, this represents a higher frequency of occurrence of driest years from period 2001–2020 than from the reference period. The exceptions present the profiles in the northern part of Slovakia (Javorinka, Poprad with Dunajec basins) and also the Danube River, where of the 10 driest years only 2 have come from the period 2001–2020. Among the 10 driest years in the individual evaluated WSs years identified as the most numerous in the period 2001-2020 in addition to the years 2012, 2003, 2007, 2004, 2008 (evaluated as the driest in the period 2001–2015 in the partial report (Poórová et al, 2018)), the years from the other 5-years have been added: 2017, 2018 and 2019.

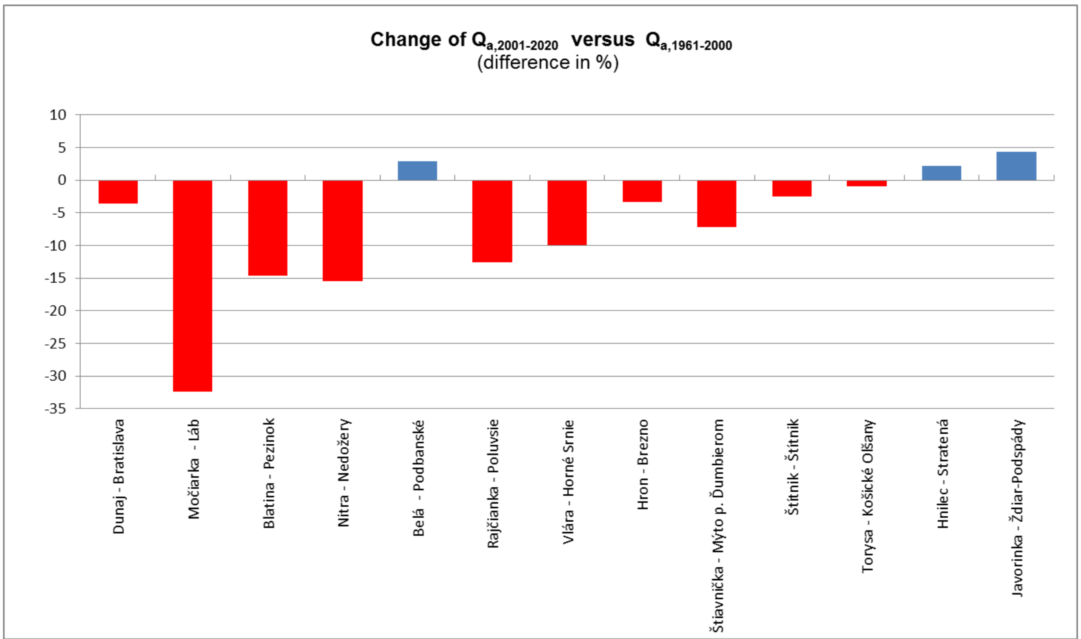


Fig. 2. The change of mean long-term discharges in the period 2001–2020 compared to reference period 1961–2000.

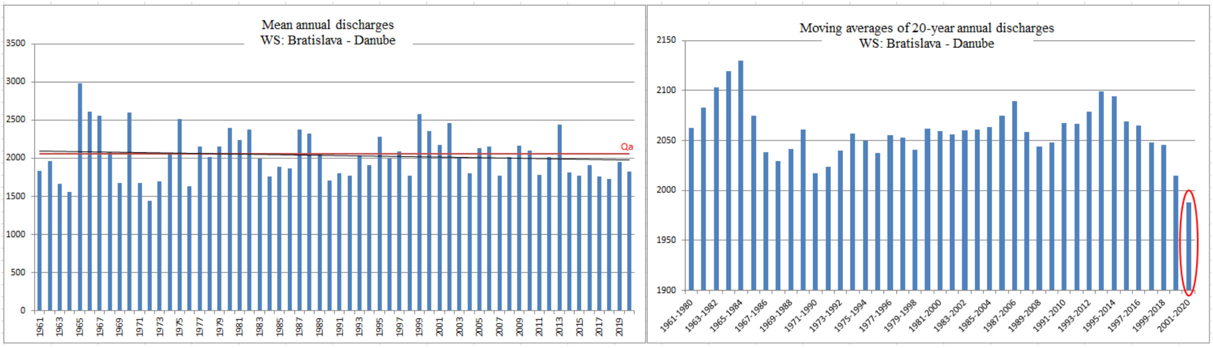


Fig. 3. Q_r series and moving averages of 20-years Q_a in the period 1961–2020, step 1 year; WS: Danube in Bratislava.

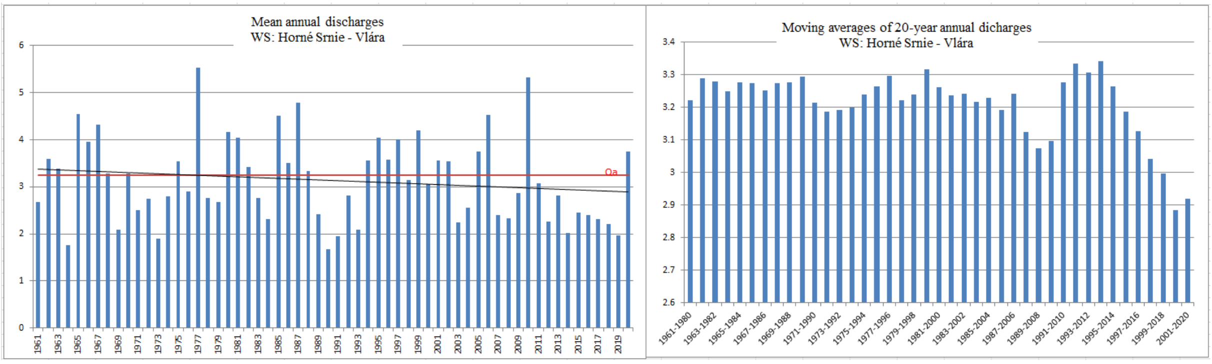


Fig. 4. Q_r series and moving averages of 20-years Q_a in the period 1961–2020, step 1 year; WS: Horné Srnie – Vlára.

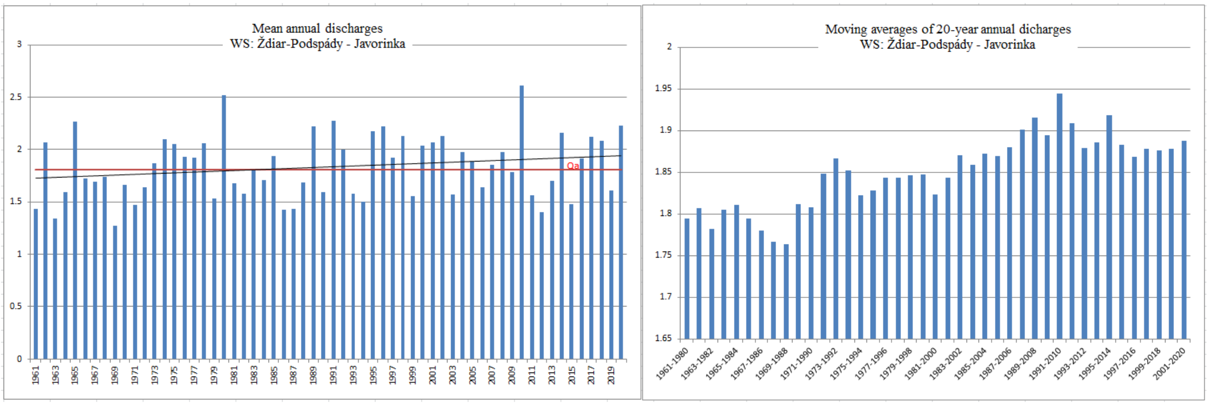


Fig. 5. Q_r series and moving averages of 20-years Q_a in the period 1961–2020, step 1 year; WS: Ždiar-Podspády – Javorinka.

When analyzing the occurrence of sub-normal mean annual discharges (Q_r <90% $Q_{a,1961\text{-}2000}$), in a larger part of the evaluated WSs the higher percentage occurrence of such years can be seen in the period 2001–2020 than in the reference period. The percentage of occurrence of such years in the period 1961–2000 among the 13 evaluated stations was about 37% on average, while in the period 2001–2020 it was almost 50%. We recorded approximately the same percentage of occurrence in both periods in 4 stations (streams Belá, Štiavnička, Torysa, Javorinka), of which only in Javorinka the share of below-average years was lower in the period 2001–2020 compared to the reference period.

Mean monthly discharges (Q_m) and long-term mean monthly discharges (Q_{ma}): When assessing monthly flows, a large part of the evaluated profiles shows an increase in long-term mean monthly discharges in the winter months (especially in January and February) in the period 2001–2020 compared to the reference period. That is considered to be a consequence of earlier snow melting, as one of the impacts of the climate change. On the contrary, the decline is visible especially in the months of April, May and also October, as we can see e.g. in the graph for WS Štítnik – Štítnik (Fig. 6).

The decrease of $Q_{ma,2001\text{-}2020}$ in WSs, where also the significant decrease of $Q_{a,2001\text{-}2020}$ has been identificated, is manifestated in most months of the year, e.g. WS Poluvsie – Rajčianka (Fig. 7). Similarly, in WSs with increase of $Q_{a,2001\text{-}2020}$ there is prevailing number of months with increase of long-term mean monthly discharge values in this period.

Since the changes in Q_{ma} are also related to the overall change of $Q_{a,2001\text{-}2020}$ compared to the reference period, we also analyzed the changes in the runoff distribution throughout the year. The changes identified in the evaluation of the period 2001–2020 in comparison with the reference period 1961–2000 have confirmed in most of the evaluated stations the results of analyzes of period 2001–2015 (Blaškovičová et al., 2019), i.e. transfer of part of the spring runoff (typical maxima in the regimes of Slovak streams in March and April) to the previous (winter) months (Fig. 8), but in some cases also to the summer months. The increase in the share of runoff in the months of January to March and the subsequent decrease in the spring months compared to the reference period, passing in the part of the evaluated WSs to the summer months, is noticeable.

Again the difference is in the WSs on the streams in the mountain areas of northern Slovakia (Podbanské – Belá, Ždiar-Podspády – Javorinka), where no significant change in the distribution of runoff was recorded in the evaluated period compared to the period 1961–2000.

Average monthly discharges classified according to water category (Table 2) in the evaluated and reference period also allow the assessment of changes in the frequency of occurrence of significantly below-average values (<60%) in the evaluated period compared to the reference period.

The occurrence of extremely dry average monthly discharges (less than 20% Q_{ma}) in some of the WSs has been not recorded at all in any of the evaluated periods (6 WSs, mostly mountain streams – Hron in Brezno, Štiavnička, Hnilec, Javorinka, and larger streams – Danube, Nitra). In other 4 WSs, a rare occurrence of such values was recorded in the reference period (1 to 4 occurrences in the period), but in the period 2001–2020 they were not recorded at all. Of the remaining three evaluated WSs, in two of them there was an increase in the incidence of extremely dry months in the period 2001–2020 compared to the reference period in terms of the length of the period (Blatina by 21%, Vlára by up to 271%), in WS Štítnik – Štítnik there was a decrease of 67% (in the reference period there were a total of 6 occurrences, in the period 2001–2020 only 1).

Dry months (Q_m < 40% Q_{ma}) were not recorded only on the Danube in the evaluated periods. The steadiness of this significantly larger river in comparison with other rivers in Slovakia can be seen in Fig. 9, with color differentiation of the monthly discharge relative values (Q_m / $Q_{ma,1961\text{-}2000}$); in the right part of the table the values are sorted from the smallest monthly values to the largest for individual months in both periods. It is obvious that in addition to the absence of Q_m / Q_{ma} < 40%, resp. 20% of long-term values there is also the rare occurrence of opposite extremes – relative monthly discharges greater than 200% Q_{ma}.

In other evaluated WSs, the increase in the frequency of occurrence of Q_m < 40% $Q_{ma,1961\text{-}2000}$ prevailed – in 6 WSs (the largest increase in WS Nedožery-Nitra (by 270%) and WS Poluvsie – Rajčianka (by 200%)). The largest increases in the frequency of dry months in individual calendar months prevailed in April, alternatively also in the summer months. There were 5 WSs without change, or only with minor changes in the frequency of occurrence (changes up to 10%, mostly an increase in the frequency of occurrence). Only in one WS (Ždiar-Podspády – Javorinka) a decrease in the frequency of Q_m < 40% Q_{ma} (by -56%) was recorded.

In the frequency of subnormal months (Q_m < 60% $Q_{ma,1961\text{-}2000}$), we recorded a predominant increase (in 8 WS), on average by 46%. In 3 WSs there were changes up to 10% (2x decrease, 1x increase) and in 2 WSs there was a decrease (by 13% and 39%). In general, the increase in the frequency of occurrence in April prevailed. We recorded a decrease in the frequency of occurrence of monthly flows less than 60% of Q_{ma} on the Torysa and Javorinka streams; the mountain streams Belá, Štiavnička and Hnilec were almost unchanged.

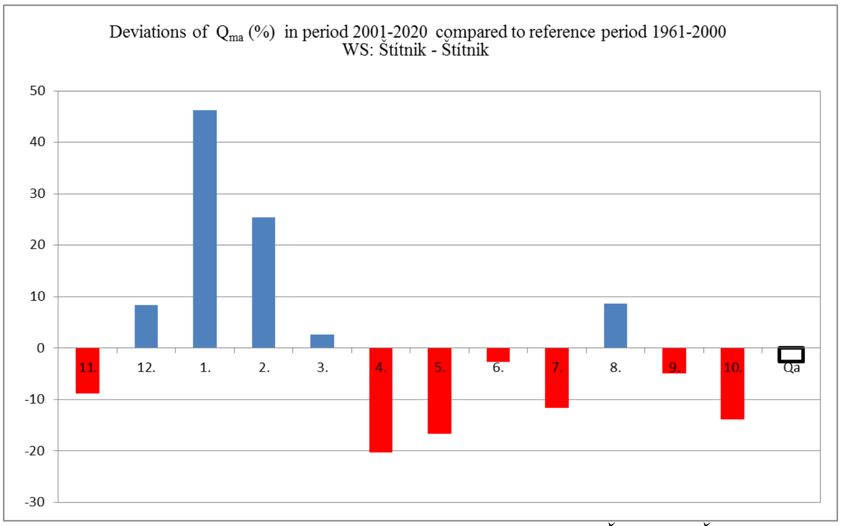


Fig. 6. Deviations of $Q_{ma,2001\text{-}2020}$ versus $Q_{ma,1961\text{-}2000}$ [%], WS Štítnik – Štítnik.

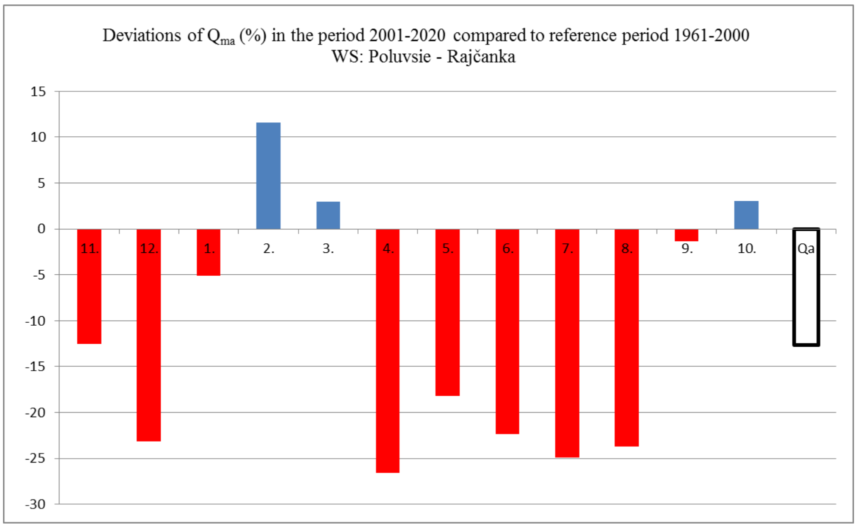


Fig. 7. Deviations of $Q_{ma,2001\text{-}2020}$ versus $Q_{ma,1961\text{-}2000}$ [%], WS Poluvsie –Rajčianka.

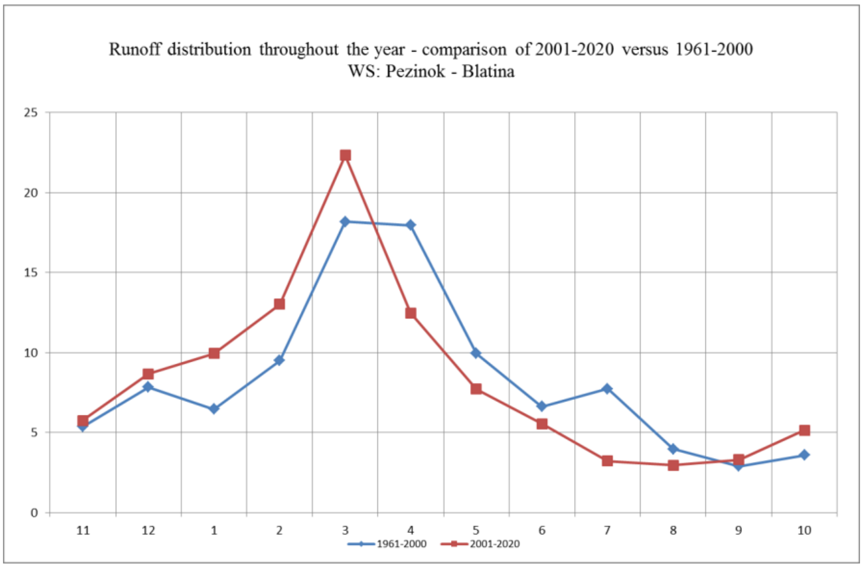


Fig. 8. The change of runoff distribution throughout the year [%] in the period 2001–2000 compared to the reference period; WS Pezinok – Blatina.

Table 2. Categories of mean monthly discharges (% of corresponding long-term $Q_{ma,1961\text{-}2000}$)

Category % Q_{ma}	Description
0–20	Extremely dry month
21–40	Dry month
41–60	Significantly subnormal month
61–80	Subnormal month
81–120	Normal month
121–160	Above normal month
161–200	Significantly wet month
> 200	Extremely wet month

Mesiac	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1961	98.7	76.9	66.0	119.9	86.1	82.1	104.1	109.6	79.3	95.8	71.1	63.2	63.3	54.9	48.5	47.0	44.6	48.1	64.2	69.3	57.3	58.8	63.9	59.9
1962	65.9	107.8	95.9	105.7	78.7	107.9	127.2	116.8	91.1	81.8	68.1	59.9	64.5	56.9	55.8	52.7	59.8	62.1	67.6	69.5	64.0	61.6	66.2	63.2
1963	66.3	59.4	58.4	47.0	98.0	101.4	88.3	87.4	75.4	78.0	100.7	90.1	65.1	59.4	58.3	54.5	62.8	65.2	68.1	72.6	64.8	62.1	68.1	65.6
1964	85.4	56.9	48.5	54.5	66.9	86.6	96.7	69.3	64.8	73.7	79.5	124.0	65.9	63.0	58.4	55.7	66.9	69.1	69.0	74.5	67.4	64.8	68.3	66.2
1965	159.1	95.3	93.7	74.0	123.4	150.0	192.1	259.5	152.2	117.9	124.8	89.7	66.3	63.4	60.6	59.4	67.2	69.3	69.1	76.2	70.9	66.5	68.7	68.3
1966	73.3	117.7	95.9	146.7	95.7	107.0	112.2	109.6	175.8	202.3	153.6	104.0	71.8	66.4	62.2	62.4	67.9	77.3	70.1	76.7	71.4	72.3	71.1	69.1
1967	108.6	148.7	149.2	142.3	139.1	125.8	126.3	140.9	112.7	90.8	107.5	88.1	72.7	67.7	66.0	64.2	70.4	77.5	75.4	77.5	75.4	73.7	72.8	72.8
1968	77.2	84.2	126.7	101.8	90.7	103.9	77.5	80.4	93.5	127.3	110.4	167.4	73.3	73.8	70.1	68.4	70.4	80.5	77.5	77.6	75.4	78.0	74.9	73.6
1969	86.7	63.4	71.8	78.7	87.7	84.5	81.0	82.2	81.1	91.0	91.8	66.2	74.9	73.8	71.1	73.5	72.8	82.1	77.9	79.6	76.8	78.9	76.4	75.2
1970	64.5	54.9	62.2	148.4	118.8	142.7	141.3	142.4	122.9	180.5	136.8	149.1	75.2	74.2	71.8	73.7	77.3	83.1	78.2	80.4	77.9	81.1	79.5	78.7
1971	137.4	104.9	76.5	73.5	77.3	83.1	68.1	89.6	71.4	64.8	72.8	72.8	75.7	76.4	76.5	74.0	78.7	83.7	79.0	80.6	79.3	81.8	79.5	78.7
1972	65.1	73.8	58.3	52.7	44.6	69.3	67.6	76.2	92.8	94.3	63.9	65.6	77.2	76.9	76.8	78.5	79.3	84.5	81.0	81.2	81.1	82.7	81.7	79.0
1973	119.2	74.2	55.8	62.4	70.4	87.7	113.7	90.9	75.4	66.5	68.3	88.4	77.9	77.5	78.2	78.7	83.6	86.1	82.4	82.1	81.1	84.8	83.2	84.2
1974	113.8	103.8	132.1	107.0	86.4	65.2	75.4	104.8	130.9	96.2	86.3	119.5	78.5	84.2	84.1	80.8	86.1	86.6	88.3	82.2	81.3	85.3	86.0	85.8
1975	115.9	217.6	167.7	109.6	70.4	89.3	108.2	100.3	186.5	114.7	111.5	84.2	83.4	85.2	87.5	85.8	86.4	87.5	94.5	84.4	81.7	85.6	86.3	86.2
1976	77.9	67.7	153.3	80.8	59.8	62.1	69.1	85.2	57.3	81.1	100.3	86.2	85.0	85.3	87.7	86.7	87.7	87.7	96.0	84.6	83.2	90.1	91.8	86.6
1977	85.7	85.6	76.8	181.7	133.9	106.3	107.3	79.6	76.8	141.6	104.6	78.7	85.4	85.6	88.6	88.1	88.3	89.0	96.4	85.2	83.4	90.5	92.3	88.1
1978	94.0	88.2	84.1	68.4	120.9	86.1	98.5	89.9	108.1	93.1	107.0	136.1	85.7	88.2	88.7	89.5	88.5	89.3	96.5	87.4	90.7	90.8	100.3	88.4
1979	85.0	73.8	78.2	104.1	126.3	117.6	107.5	127.8	107.5	102.9	100.6	90.8	86.0	89.5	89.2	92.6	90.7	92.7	96.7	89.6	91.1	91.0	100.6	89.7
1980	143.5	144.4	87.7	138.4	72.8	116.7	112.5	113.0	142.5	107.5	101.5	123.4	86.7	94.7	93.7	96.9	95.7	95.4	98.5	89.9	92.8	93.1	100.7	90.1
1981	97.9	99.7	110.9	108.4	155.2	106.6	78.2	74.5	118.3	104.3	102.0	177.1	89.3	95.3	95.9	101.8	96.2	101.2	102.4	90.9	93.5	94.3	101.5	90.8
1982	173.8	156.5	175.9	143.4	97.7	95.4	102.6	112.6	94.9	100.0	86.0	93.3	90.3	96.0	95.9	104.1	97.7	101.4	102.6	93.4	94.9	95.8	102.0	91.3
1983	78.5	89.5	157.8	113.9	102.6	112.5	96.4	93.4	77.9	85.6	81.7	79.0	93.7	99.5	101.1	105.7	98.0	103.4	102.8	94.5	97.0	96.2	103.0	93.0
1984	63.3	76.4	89.2	85.8	62.8	80.5	82.4	81.2	81.1	90.1	130.2	115.4	94.0	99.7	101.7	106.4	99.9	103.9	102.9	95.5	97.2	96.2	104.6	93.3
1985	72.7	63.0	60.6	117.4	79.3	77.3	94.5	94.5	81.7	158.6	113.6	73.6	97.9	100.7	102.0	107.0	102.1	106.3	104.1	98.4	99.4	97.9	107.0	96.2
1986	71.8	96.0	145.3	78.5	83.6	101.2	102.8	101.3	70.9	78.9	76.4	75.2	98.6	101.2	107.6	108.4	102.6	106.6	107.3	100.3	105.1	99.3	107.5	103.3
1987	74.9	66.4	119.2	108.6	129.9	128.3	122.0	134.9	129.4	128.9	103.0	91.3	98.7	103.8	110.9	108.6	110.5	107.0	107.5	101.3	106.5	100.0	107.7	104.0
1988	93.7	136.3	102.0	92.6	165.4	167.2	109.9	95.5	81.3	90.5	122.6	86.6	108.6	104.9	111.5	109.6	112.6	107.9	108.2	104.8	107.5	102.9	109.2	110.4
1989	89.3	187.2	125.1	96.9	88.5	83.7	77.9	77.5	99.4	99.3	109.2	112.3	113.8	106.5	115.1	113.9	114.4	112.5	108.3	109.6	108.1	104.3	110.4	112.3
1990	98.6	85.2	70.1	106.4	102.1	69.1	69.0	80.6	97.2	61.6	83.2	85.8	113.9	107.8	119.2	117.4	118.8	113.4	109.9	109.6	108.5	107.5	111.5	115.4
1991	114.2	77.5	111.5	55.7	67.2	48.1	79.0	98.4	105.1	152.0	66.2	69.1	114.2	117.7	125.1	119.9	120.9	116.7	111.8	112.6	112.7	108.3	113.6	119.5
1992	75.7	100.7	88.7	88.1	112.6	103.4	102.9	82.1	67.4	58.8	68.7	78.7	115.9	120.7	126.7	128.5	123.4	117.6	112.2	113.0	118.3	114.7	114.2	123.4
1993	163.2	137.6	101.1	73.7	96.2	87.5	70.1	69.5	108.5	96.2	114.2	110.4	119.2	120.9	132.1	138.4	126.3	125.8	112.5	113.5	122.9	117.9	122.6	124.0
1994	83.4	120.7	132.2	89.5	110.5	126.4	96.0	84.6	64.0	62.1	79.5	68.3	137.4	136.3	132.2	140.8	129.9	126.4	113.7	116.8	129.4	127.3	124.8	132.4
1995	90.3	85.3	115.1	128.5	99.9	127.4	102.4	139.1	97.0	84.8	156.6	93.0	139.8	137.6	145.3	142.3	133.9	127.4	122.0	127.8	130.9	128.9	128.5	136.1
1996	113.9	101.2	88.6	59.4	67.9	92.7	108.3	76.7	90.7	82.7	142.3	167.1	143.5	144.4	149.2	143.4	139.1	128.3	126.3	134.9	142.5	141.6	130.2	144.6
1997	139.8	94.7	71.1	86.7	114.4	89.0	96.5	77.6	164.0	97.9	74.9	103.3	159.1	148.7	153.3	146.7	155.2	137.8	127.2	139.1	152.2	152.0	136.8	149.1
1998	75.2	106.5	87.5	64.2	88.3	77.5	64.2	72.6	83.2	72.3	128.5	144.6	163.2	156.5	157.8	148.4	162.1	142.7	141.3	140.9	164.0	158.6	142.3	167.1
1999	220.6	120.9	107.6	140.8	162.1	113.4	158.4	113.5	106.5	85.3	92.3	96.2	173.8	187.2	167.7	164.0	165.4	150.0	158.4	142.4	175.8	180.5	153.6	167.4
2000	86.0	99.5	101.7	164.0	166.0	137.8	111.8	84.4	83.4	108.3	107.7	132.4	220.6	217.6	175.9	181.7	166.0	167.2	192.1	259.5	186.5	202.3	156.6	177.1
2001	97.4	80.0	95.7	103.2	147.3	114.4	95.2	106.0	86.7	79.5	163.8	100.6	62.3	57.2	60.7	65.1	55.7	55.4	52.0	58.5	50.9	49.0	65.4	68.4
2002	97.5	122.8	123.0	140.7	163.3	91.2	87.2	80.9	71.9	193.0	131.4	183.6	66.7	62.9	66.4	70.5	71.4	56.5	58.8	63.2	56.1	50.9	68.1	77.8
2003	248.8	154.9	184.0	102.9	96.6	69.8	76.5	64.9	50.9	50.9	68.1	113.8	66.9	65.4	67.1	74.9	73.3	58.2	64.0	64.3	58.5	58.4	69.1	79.5
2004	68.0	57.2	113.9	108.9	93.1	90.2	78.4	100.7	85.1	72.9	88.6	96.1	67.6	66.1	72.7	76.0	77.3	59.6	72.8	64.9	67.7	71.4	79.8	82.0
2005	95.3	65.4	90.7	103.6	122.8	118.6	107.2	73.1	109.3	135.3	106.6	101.3	68.0	67.3	75.0	79.4	78.9	69.8	76.5	65.6	70.9	72.9	80.0	89.2
2006	67.6	67.3	67.1	74.9	128.2	186.9	123.1	115.5	72.1	118.2	96.2	77.8	79.1	69.7	78.2	79.9	92.1	71.6	78.4	68.1	71.9	73.1	84.1	92.0
2007	100.5	62.9	99.3	94.3	97.6	58.2	64.0	64.3	75.5	71.4	186.7	105.3	92.9	75.0	87.2	87.7	93.1	72.1	82.0	73.1	72.1	76.7	88.6	96.1
2008	145.6	127.4	106.5	79.4	109.6	96.1	92.5	83.4	91.5	97.7	79.8	82.0	95.3	78.4	90.7	88.3	96.6	72.4	86.4	80.9	73.4	77.1	94.5	97.0
2009	79.1	87.8	66.4	65.1	140.9	135.2	101.3	119.4	129.0	95.9	94.6	97.0	95.7	79.6	95.7	94.3	97.6	85.3	87.2	81.8	75.5	79.5	94.6	98.9
2010	96.9	88.3	87.2	76.0	101.0	72.4	90.2	142.5	91.5	132.7	132.3	98.9	96.9	80.0	99.3	95.0	100.6	86.9	88.5	83.4	79.5	92.2	96.2	100.6
2011	95.7	111.6	172.9	95.0	71.4	59.6	52.0	65.6	79.5	92.2	84.1	120.5	97.4	80.3	106.5	98.8	101.0	87.0	90.2	86.6	84.2	95.8	106.6	101.3
2012	66.7	79.6	164.1	88.3	115.3	87.0	86.4	112.0	86.4	76.7	113.3	111.6	97.5	87.8	113.9	102.1	106.6	90.2	92.5	100.7	84.8	95.9	110.5	105.3
2013	105.7	117.7	170.8	147.7	100.6	101.9	102.8	191.7	84.8	73.1	120.8	114.8	100.0	88.3	123.0	102.9	109.6	91.2	94.2	106.0	85.1	97.7	113.3	111.6
2014	128.1	80.3	78.2	70.5	55.7	55.4	94.2	63.2	73.4	115.9	144.5	137.0	100.5	97.0	123.2	103.2	115.3	92.1	95.2	112.0	86.4	102.7	120.8	112.0
2015	112.7	78.4	144.9	79.9	77.3	92.1	109.2	86.6	58.5	58.4	65.4	79.5	105.7	103.0	144.9	103.6	122.8	96.1	101.3	112.4	86.7	107.1	127.5	113.8
2016	66.9	69.7	75.0	135.6	78.9	71.6	82.0	118.8	106.4	107.1	94.5	92.0	112.7	111.6	164.1	108.9	128.2	101.9	102.8	115.5	91.5	115.9	131.4	114.8
2017	100.0	66.1	60.7	87.7	106.6	72.1	88.5	58.5	70.9	95.8	127.5	112.0	127.9	117.7	170.8	135.6	130.2	114.4	107.2	118.8	91.5	118.2	132.3	120.5
2018	127.9	103.0	187.1	102.1	73.3	86.9	72.8	68.1	56.1	49.0	69.1	68.4	128.1	122.8	172.9	136.7	140.9	118.6	108.2	119.4	106.4	132.7	144.5	136.4
2019	62.3	97.0	123.2	98.8	130.2	85.3	108.2	112.4	67.7	77.1	80.0	89.2	145.6	127.4	184.0	140.7	147.3	135.2	109.2	142.5	109.3	135.3	163.8	137.0
2020	92.9	75.0	72.7	136.7	92.1	56.5	58.8	81.8	84.2	102.7	110.5	136.4	248.8	154.9	187.1	147.7	163.3	186.9	123.1	191.7	129.0	193.0	186.7	183.6

Fig. 9. Relative values of mean monthly discharges $Q_m/Q_{ma,1961\text{-}2000}$ and their sorting by categories (on the right) in both assessed periods (WS Bratislava – Danube).

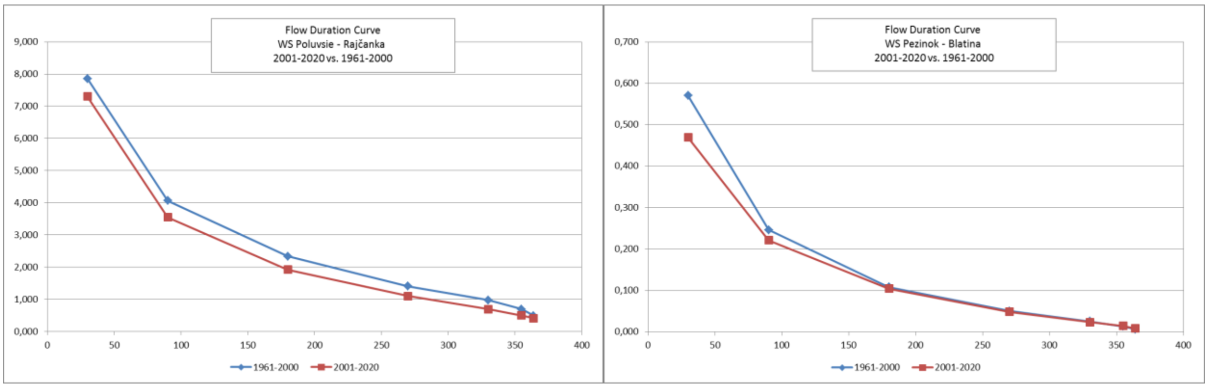
Mesiac	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1961	81.8	85.6	76.9	102.1	77.3	110.4	60.4	121.6	83.7	43.5	27.5	38.2	20.9	18.3	23.7	14.5	18.6	20.8	26.0	27.5	19.4	9.3	17.6	13.8
1962	102.9	99.4	110.7	49.9	133.3	181.2	222.5	101.0	51.5	38.8	40.7	31.5	24.0	25.1	26.1	23.2	22.3	40.2	26.9	28.3	20.8	21.0	19.4	15.3
1963	164.9	75.8	110.8	50.8	155.4	92.0	130.8	103.5	43.8	53.2	81.5	157.1	25.5	26.1	27.3	24.4	31.4	48.4	29.8	30.4	22.9	21.0	22.7	17.9
1964	112.8	34.0	44.4	33.8	72.4	48.4	33.3	39.8	86.8	29.4	19.4	117.6	28.2	30.7	29.8	27.8	47.5	48.7	33.3	30.8	23.8	23.9	24.8	25.0
1965	83.3	73.8	93.2	89.0	115.1	112.0	263.6	438.7	169.8	175.9	79.8	39.5	28.4	34.0	32.4	28.6	48.9	49.4	34.1	33.8	25.8	24.4	26.9	25.1
1966	56.4	166.5	86.7	206.2	63.6	61.8	82.2	105.3	289.0	278.2	142.9	61.0	29.1	44.6	38.4	33.8	50.6	51.1	40.7	37.9	27.8	25.5	27.5	28.1
1967	93.8	194.8	110.5	237.6	234.4	119.7	56.7	53.3	20.8	21.0	41.1	25.1	29.4	45.3	44.4	35.3	55.3	55.4	44.3	38.5	30.8	27.3	28.5	28.7
1968	28.2	89.5	93.0	205.2	101.8	48.7	44.3	99.6	37.4	140.0	222.0	158.5	30.2	46.9	51.8	37.5	55.4	58.0	45.7	38.8	33.0	27.9	29.7	28.8
1969	76.9	46.9	86.3	141.7	79.7	51.1	29.8	28.3	25.8	49.2	28.5	13.8	31.7	48.7	56.9	40.6	59.9	59.8	49.6	39.8	34.2	29.4	35.8	29.2
1970	46.4	18.3	62.7	28.6	161.4	210.9	64.6	82.6	227.0	94.6	49.7	76.8	31.7	54.2	62.6	44.1	59.9	60.7	52.8	45.9	34.6	33.4	36.0	30.7
1971	173.3	76.2	116.0	55.7	70.7	81.2	95.5	72.7	49.9	27.3	35.8	25.0	33.3	57.0	62.7	49.9	62.1	61.8	56.7	46.1	34.7	38.8	36.5	31.5
1972	31.7	63.2	38.4	27.8	22.3	59.8	105.8	72.8	401.8	325.5	125.8	66.1	38.4	61.1	75.4	50.8	63.5	71.7	56.8	49.1	35.8	40.3	38.3	34.0
1973	72.6	44.6	27.3	93.0	73.9	101.9	49.6	27.5	23.8	27.9	29.7	28.7	46.4	63.2	76.9	55.7	63.6	72.5	60.4	52.6	37.4	43.5	40.7	38.2
1974	33.3	83.3	162.1	77.9	18.6	20.8	26.9	86.8	84.7	84.9	91.5	632.1	47.6	66.1	80.0	61.0	67.7	73.8	60.7	52.6	42.3	45.3	41.1	39.5
1975	150.6	326.5	126.5	40.6	50.6	93.7	60.7	102.5	173.6	94.8	51.6	85.3	56.4	67.0	83.1	65.4	69.8	77.2	64.6	53.3	43.6	45.7	49.7	40.3
1976	47.6	67.0	261.4	61.0	59.9	85.5	120.8	82.9	48.9	56.8	70.7	71.3	71.0	73.0	85.7	69.7	70.7	79.1	66.8	58.2	43.7	49.2	50.7	40.7
1977	130.9	282.3	133.1	321.5	78.6	188.9	150.5	70.8	43.6	475.7	133.6	56.0	72.6	73.8	85.8	76.8	72.4	81.2	72.1	61.4	43.8	49.8	51.6	45.5
1978	287.4	48.7	62.6	76.8	55.4	129.8	116.4	45.9	43.7	45.7	54.9	100.3	76.9	75.8	86.3	77.2	73.9	85.5	76.8	64.0	46.8	50.0	53.4	45.6
1979	29.4	76.8	108.6	121.9	79.8	72.5	96.4	113.5	46.8	63.8	74.0	30.7	81.8	76.2	86.7	77.9	77.3	90.3	77.3	70.8	48.9	51.6	54.9	48.2
1980	159.8	187.0	56.9	124.4	69.8	147.5	138.8	52.6	202.7	164.4	215.0	220.2	83.3	76.3	93.0	78.8	78.6	92.0	78.5	72.7	49.9	53.2	68.2	48.9
1981	134.9	167.0	119.5	85.6	224.8	55.4	66.8	58.2	81.1	71.4	137.1	242.3	93.8	76.8	93.2	81.1	79.7	92.9	82.2	72.8	51.0	56.8	69.5	49.8
1982	173.2	134.7	226.9	44.1	101.8	58.0	72.1	64.0	169.7	118.5	69.5	48.9	100.5	80.5	94.9	85.6	79.8	93.1	87.5	82.6	51.5	57.4	70.7	56.0
1983	29.1	66.1	163.2	88.1	119.4	119.5	87.5	37.9	34.2	23.9	26.9	28.8	102.9	83.3	107.7	87.3	96.5	93.7	95.5	82.9	54.5	63.8	74.0	61.0
1984	20.9	25.1	26.1	65.4	67.7	93.1	125.2	46.1	42.3	57.4	274.9	161.4	105.0	85.6	108.6	88.1	101.5	101.9	96.4	86.8	55.4	71.3	79.8	61.5
1985	255.1	54.2	85.7	77.2	157.3	60.7	202.5	186.4	68.7	653.4	89.0	45.5	112.8	89.5	110.5	89.0	101.8	107.8	103.5	93.0	66.0	71.4	81.5	66.1
1986	134.8	164.6	159.5	87.3	115.3	71.7	45.7	231.5	34.7	71.3	68.2	48.2	118.1	95.2	110.7	93.0	101.8	110.4	105.8	99.6	68.7	73.0	89.0	69.7
1987	30.2	45.3	112.1	322.1	96.5	158.4	254.1	319.4	66.0	79.8	53.4	45.6	130.9	99.4	110.8	102.1	115.1	112.0	107.0	101.0	81.1	79.8	91.5	71.3
1988	100.5	170.9	94.9	81.1	159.5	130.3	77.3	52.6	27.8	33.4	100.9	28.1	134.8	114.1	112.1	114.2	115.3	115.2	116.4	102.5	83.7	84.9	100.9	74.2
1989	24.0	183.2	75.4	123.6	59.9	49.4	76.8	38.8	30.8	49.8	50.7	34.0	134.9	116.5	116.0	121.9	119.4	119.5	120.8	103.5	84.7	94.6	102.2	76.8
1990	28.4	73.0	23.7	35.3	47.5	77.2	78.5	49.1	51.0	21.0	102.2	40.3	142.4	118.2	119.5	123.6	133.3	119.7	125.2	105.3	86.8	94.8	116.1	85.3
1991	142.4	80.5	80.0	24.4	55.3	40.2	107.0	61.4	33.0	50.0	24.8	17.9	150.6	134.7	123.8	124.4	134.4	129.8	130.8	113.5	91.0	96.1	125.8	100.3
1992	118.1	26.1	123.8	134.6	157.2	90.3	52.8	30.8	19.4	9.3	17.6	29.2	150.7	164.6	126.5	134.6	155.4	130.3	138.8	121.6	144.6	114.3	133.6	117.6
1993	25.5	57.0	107.7	23.2	134.4	79.1	26.0	30.4	22.9	25.5	36.0	69.7	158.4	166.5	133.1	141.7	157.2	147.5	150.5	124.4	169.7	118.5	137.1	157.1
1994	31.7	116.5	214.7	78.8	62.1	196.9	174.1	136.1	34.6	45.3	36.5	61.5	159.8	167.0	135.7	147.6	157.3	155.3	174.1	136.1	169.8	140.0	142.9	158.5
1995	71.0	118.2	135.7	147.6	101.5	155.3	188.1	186.8	55.4	40.3	165.4	49.8	164.9	170.9	159.5	200.0	159.5	156.8	180.6	186.4	173.6	164.4	165.4	161.4
1996	105.0	76.3	85.8	14.5	63.5	156.8	180.6	124.4	144.6	96.1	399.3	205.3	173.2	183.2	162.1	205.2	161.4	158.4	188.1	186.8	202.7	175.9	215.0	205.3
1997	158.4	61.1	32.4	114.2	48.9	92.9	103.5	93.0	747.5	114.3	116.1	74.2	173.3	187.0	163.2	206.2	195.8	181.2	202.5	231.5	227.0	278.2	222.0	220.2
1998	150.7	114.1	51.8	37.5	31.4	73.8	34.1	38.5	35.8	24.4	555.0	678.6	255.1	194.8	214.7	237.6	224.8	188.9	222.5	279.0	289.0	325.5	274.9	242.3
1999	263.5	95.2	83.1	69.7	226.2	107.8	56.8	279.0	91.0	73.0	38.3	40.7	263.5	282.3	226.9	321.5	226.2	196.9	254.1	319.4	401.8	475.7	399.3	632.1
2000	38.4	30.7	29.8	200.0	195.8	115.2	40.7	33.8	54.5	51.6	22.7	15.3	287.4	326.5	261.4	322.1	234.4	210.9	263.6	438.7	747.5	653.4	555.0	678.6
2001	138.5	49.0	95.1	54.8	128.7	134.0	50.8	26.7	306.8	97.6	333.3	75.4	11.7	18.3	31.9	38.1	24.1	20.4	23.7	15.0	12.4	9.0	10.4	16.5
2002	82.4	24.1	193.7	226.6	58.0	48.1	42.7	39.1	79.4	160.2	91.2	462.8	15.9	18.8	33.7	42.3	37.6	22.9	24.6	19.1	15.1	12.9	21.7	21.6
2003	209.0	94.3	193.0	38.1	48.3	55.7	29.7	42.6	35.4	12.9	10.4	22.7	20.7	24.1	34.8	42.8	44.1	27.1	25.1	22.8	16.2	16.4	22.9	22.7
2004	20.7	37.7	80.9	132.5	123.9	48.3	55.0	128.0	53.9	40.5	31.8	49.4	26.7	34.1	46.4	48.7	48.3	29.0	28.2	22.9	18.8	19.4	29.7	30.6
2005	123.2	63.6	155.9	42.8	167.3	180.9	166.3	46.0	74.0	140.1	62.0	30.6	27.4	37.7	55.2	54.8	52.7	38.6	29.7	26.7	19.4	21.2	31.7	34.6
2006	27.4	76.7	99.3	89.0	256.8	275.7	182.6	90.3	47.7	82.1	62.2	40.6	53.1	42.5	55.6	58.1	53.4	41.9	33.8	26.8	28.9	22.8	31.8	35.6
2007	90.2	34.1	102.6	104.3	121.2	41.9	33.8	58.6	33.1	37.3	127.5	48.2	54.0	49.0	76.0	58.3	58.0	42.5	42.2	30.7	32.1	25.0	38.9	40.0
2008	145.0	90.9	123.0	48.7	71.1	57.8	51.6	30.7	47.5	131.4	39.4	35.6	59.4	51.5	80.9	64.5	61.3	45.2	42.7	31.2	33.1	37.3	39.4	40.4
2009	26.7	59.1	76.0	42.3	268.5	71.5	25.1	31.2	44.5	22.8	21.7	87.1	60.0	53.1	95.1	89.0	63.7	48.1	43.3	39.1	35.4	40.5	41.3	40.6
2010	117.1	128.8	137.5	159.3	83.9	65.1	356.9	426.3	83.8	127.9	459.3	108.5	76.7	54.9	99.3	100.5	63.9	48.3	50.8	42.6	41.2	43.9	47.7	48.2
2011	146.0	236.1	139.3	64.5	37.6	42.5	55.6	46.0	219.3	159.6	41.3	34.6	82.4	58.5	102.6	104.3	71.1	55.7	51.6	44.4	44.5	49.4	58.4	49.4
2012	15.9	18.3	112.4	100.5	149.1	38.6	23.7	47.5	28.9	19.4	22.9	96.7	90.2	59.1	112.4	110.0	83.9	57.8	54.1	46.0	47.5	82.1	62.0	70.5
2013	59.4	42.5	55.6	145.2	107.5	134.5	72.0	97.6	16.2	25.0	139.0	40.4	113.7	63.6	123.0	130.3	107.5	65.1	55.0	46.0	47.7	97.6	62.2	75.4
2014	54.0	51.5	46.4	58.1	24.1	29.0	43.3	19.1	32.1	123.5	418.3	237.3	117.1	76.7	137.5	132.5	121.2	71.5	55.6	47.5	53.9	123.5	91.2	87.1
2015	113.7	84.9	151.9	110.0	61.3	100.5	42.2	22.8	15.1	43.9	31.7	21.6	123.2	84.9	139.3	140.8	123.9	100.5	72.0	58.6	65.8	127.9	127.5	96.7
2016	53.1	54.9	55.2	184.0	44.1	45.2	54.1	26.8	41.2	250.7	47.7	70.5	138.5	90.9	151.9	145.2	128.7	114.6	113.0	90.3	74.0	131.4	139.0	108.5
2017	76.7	53.1	33.7	130.3	53.4	114.6	113.0	22.9	18.8	16.4	58.4	111.8	145.0	94.3	155.9	147.9	149.1	134.0	166.3	97.6	79.4	140.1	172.0	111.8
2018	167.9	139.5	198.2	58.3	52.7	27.1	28.2	15.0	12.4	9.0	29.7	16.5	146.0	128.8	193.0	159.3	167.3	134.5	177.8	128.0	83.8	159.6	333.3	237.3
2019	11.7	18.8	34.8	140.8	63.9	20.4	177.8	44.4	19.4	21.2	38.9	40.0	167.9	139.5	193.7	184.0	256.8	180.9	182.6	233.9	219.3	160.2	418.3	462.8
2020	60.0	58.5	31.9	147.9	63.7	22.9	24.6	233.9	65.8	49.4	172.0	1026.3	209.0	236.1	198.2	226.6	268.5	275.7	356.9	426.3	306.8	250.7	459.3	1026.3

Fig. 10. Relative values of mean monthly discharges $Q_m/Q_{ma,1961\text{-}2000}$ and their sorting by categories (on the right) in both assessed periods (WS Horné Sŕnie – Vlára).

In comparison with the above picture of monthly flows on the Danube, an example of WS with less balanced monthly discharges is e.g. WS Horné Sŕnie – Vlára (Fig. 10), where we can see both the occurrence (and increase in frequency) of dry and extremely dry monthly discharges (< 40% Q_{ma}, < 20% Q_{ma}) as well as the occurrence of extremely wet months (> 200% Q_{ma}).
Flow Duration Curve (M-day discharges (Q_{Md})): Comparing the values of M-day discharges in the period 2001–2020 compared to the reference period (tab. 3) in the area of lowest discharges we have identified the increase of values of Q_{364d} in 8 WSs, from these in 1 *WS* the change is less than 5% (Danube). The decrease has been found in 5 WSs, two of them less than 5%. Similar it has been in evaluation of changes in Q_{355d}: increase in 8 WSs (in 2 WSs less than 5%), decrease in 5 WSs (in 1 WS less than 5%). For Q_{330d} the increase has been found in 7 WSs and the decrease in 6 WSs; for Q_{270d} there has been found the increase in 8 WSs and the decrease in 5 WSs.
The decrease in the smallest quantiles Q_{355d} and Q_{364d} is the largest in percentage terms in WSs Nedožery-Nitra (- 30%; -31%), Horné Sŕnie – Vlára (-25%; -43%) and Poluvsie – Rajčianka (-28%, - 15%) (Fig. 11a). These are WSs, where a decrease in Q_a in the evaluated period by more than 10% has been also recorded. The streams Močiarka and Blatina (SW Slovakia) also show a relatively significant decrease in Q_a (-32%, -15%), however, there has been identified an increase in values of the quantiles Q_{355d} and Q_{364d} (Fig. 11b).
Non-flow characteristics: The results of the evaluation of the number of days with Q_d less than or equal to the selected flow limits (calculated with respect to the different lengths of the compared periods) partially correspond to the changes in the values of M-day flows (Table 4).
For the limit $Q_{364d,1961\text{-}2000}$, the frequencies of occurrence of sublimit daily discharges in the period 2001–2020 in the already mentioned WSs on the streams Nitra, Rajčianka and Vlára (with a significant decrease in Q_a and Q_{364d} in the evaluated period) were 4.6 to 7.0 times higher than in the reference period. In other evaluated stations we recorded a significantly lower frequency of days with $Q_d \leq Q_{364d,1961\text{-}2000}$. In WS Mýto p. Ďumbierom – Štiavnička, Brezno – Hron, Pezinok - Blatina and Štítnik – Štítnik the frequency of occurrence has decreased by 40.5 to 68.6%. In 4 WSs the period 2001–2020 was even without any recorded occurrence of sublimit days and in 1 WS there was a decrease of almost 100%. These were the mountain streams Belá, Hnilec and Javorinka, and WSs Láb – Močiarka and Košické Olšany – Torysa. On the Danube in Bratislava, the frequency of occurrence of $Qd \leq Q_{364d,1961\text{-}2000}$ in the evaluated period was up to 81% lower compared to the reference period, while in the reference period of 40 years, such below-limit discharges occurred only in 5 years (1962, 1963, 1964, 1972 and 1991; months I, II and XII).
At the Q_{355d} limit, we recorded a decrease in the frequency of below-limit Q_d in 7 WSs, including the Danube River (Močiarka, Blatina, Hron, Torysa, Hnilec, Javorinka and Danube).
The increase has been significantly manifested on Rajčianka (+478%), Nitra (+341%), and Vlára (+97%); on Belá, Štiavnička and Štítnik there was an increase of 5 to 44%.
Sublimit flows for limit Q_{330d} show an increase in 7 WSs (largest on Belá (+186%) and Nitra (+150%), in other WSs there was a decrease in the frequency of occurrence ranging from -6% (Hron – Brezno) to -53% (Javorinka – Ždiar-Podspády).
At the Q_{270d} limit, the decrease in the frequency of occurrence of sublimit Q_d in the evaluated period in comparison with the reference one prevails in WSs (decrease in 9 WSs, increase in 4 WSs). The largest increase has been identified in Belá in Podbanské (+254%).

Table 3. Changes in M-day discharge kvantiles (in %) in the period 2001–2020 compared to the reference period 1961–2000 (decrease marked in light red)

Stream	WS	Q_{30d}	Q_{90d}	Q_{180d}	Q_{270d}	Q_{330d}	Q_{355d}	Q_{364d}
Dunaj	Bratislava	-5.7	-6.7	-4.5	0.3	4.4	3.5	4.5
Močiarka	Láb	-32.9	-33.9	-29.3	-27.0	-11.3	13.9	87.0
Blatina	Pezinok	-17.7	-10.2	-3.7	-4.0	-6.7	7.7	33.3
Nitra	Nedožery	-14.6	-12.9	-13.3	-26.0	-28.8	-30.0	-31.2
Belá	Podbanské	0.1	1.1	7.9	15.7	11.0	11.1	-2.9
Vlára	Horné Sŕnie	-7.8	-21.7	-19.4	-16.8	-28.3	-25.4	-43.1
Rajčianka	Poluvsie	-7.1	-12.6	-17.6	-21.7	-29.1	-27.8	-15.1
Hron	Brezno	-9.9	-3.1	9.0	5.2	0.7	4.8	8.5
Štiavnička	Mýto p. Ď.	-15.7	-2.7	4.4	8.2	2.1	-2.0	5.8
Štítnik	Štítnik	0.3	-2.4	2.4	-6.6	-2.9	-8.8	-2.1
Torysa	Košické Olšany	-12.9	-0.6	5.7	11.5	12.0	12.0	3.2
Hnilec	Stratená	-12.0	-2.0	12.2	25.1	16.7	23.0	25.0
Javorinka	Podspády	-0.3	1.1	6.9	17.6	17.4	20.8	33.2



a *b*

Fig. 11. Different types of changes of Q_{Md} values in two WSs with decrease in Q_a: a) Poluvsie – Rajčianka, b) Pezinok – Blatina.

Table 4. Changes in the frequency of occurrence $Qd \leq$ limit for Q_{270d}, Q_{330d}, Q_{355d}, Q_{364d} in the period 2001–2020 compared to the reference period 1961–2000 (difference in %, converted to the same length of the period)

Stream	Water-gauging station	$Q_d \leq$ limit			
		Q_{270d}	Q_{330d}	Q_{355d}	Q_{364d}
Dunaj	Bratislava	-1.2	-21.1	-29.1	-81.1
Močiarka	Láb	74.6	72.2	-51.4	*
Blatina	Pezinok	-1.4	20.6	-7.6	-57.4
Nitra	Nedožery	39.4	149.8	341.3	547.1
Belá	Podbanské	254.2	185.6	5.2	*
Vlára	Horné Sŕnie	-4.7	36.5	97.2	361.5
Rajčianka	Poluvsie	-2.5	47.2	478.0	602.0
Hron	Brezno	-8.6	-6.2	-35.8	-65.3
Štiavnička	Mýto p. Ď.	-16.5	-15.5	18.1	-68.6
Štítnik	Štítnik	11.1	9.7	44.2	-40.5
Torysa	Košické Olšany	-15.7	-41.4	-65.4	*
Hnilec	Stratená	-35.9	-36.5	-46.6	*
Javorinka	Podspády	-23.3	-52.8	-86.8	-96.1

* *without occurence of $Qd \leq$ limit in period 2001–2020*

Conclusion

The results of analyzes in 13 selected water-gauging stations in Slovakia, in which we compared the hydrological characteristics with respect to drought assessment, showed in the period 2001–2020 compared to the reference period 1961–2000 differences in long-term characteristics as well as changes in the occurrence of some discharge characteristics, which we classify as low-flow characteristics. Changes in comparison with the evaluation for the period 2001–2015 (in partial reports Drought assessment, SHMI), confirm the deviations of the characteristics from the reference period, in some profiles also their deepening. For example, the decrease in Q_a in the period 2001–2020 compared to the reference period 1961–2000 recorded in the evaluated WSs with the exception of mountain streams is even more pronounced in comparison with the period 2001–2015 in most stations, e.g. in WS Pezinok – Blatina the decrease in Q_a in comparison with the reference period decreased from the difference -7.6% for the period 2001–2015 to -14.7% for the period 2001–2020. Negative changes in the runoff regime have been also recorded for other characteristics, e.g. at an increased frequency of extreme flow values, as can be seen e.g. in the left part of fig. 10, where an increase in the incidence of $Q_m < 20\%\ Q_{ma,1961\text{-}2000}$ is evident in the last years of the evaluated 20-year period. Changes in the distribution of runoff are also evident in the comparison of average values from 12 stations (excluding WS Danube – Bratislava) for both periods (Fig. 12).

The changes as well as their regional differences evaluated so far only in 13 water-gauging stations point to the need for their further comprehensive evaluation in larger number of WSs on the surface flows of Slovakia

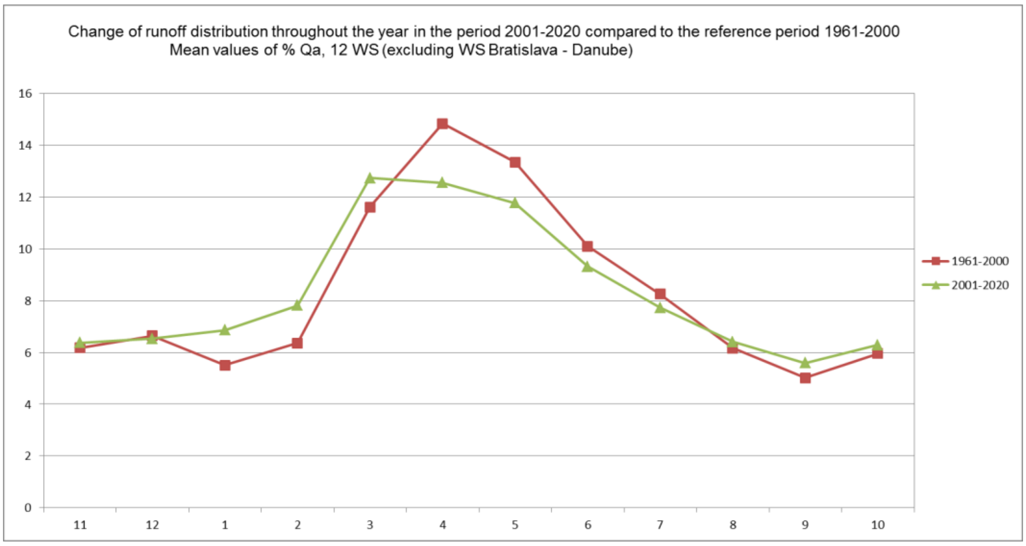


Fig. 12. Change of the runoff distribution throughout the year in the period 2001–2020 compared to the reference period 1961-2000 based on averages from values of 12 WSs.

and according to the size of the analyzed deviations and trends after 2000 and confirmation of their country-wide, resp. regional changes considering the need of changing the reference period.

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