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Detection of changes in the mean monthly discharges on the Vah River basin in Slovakia

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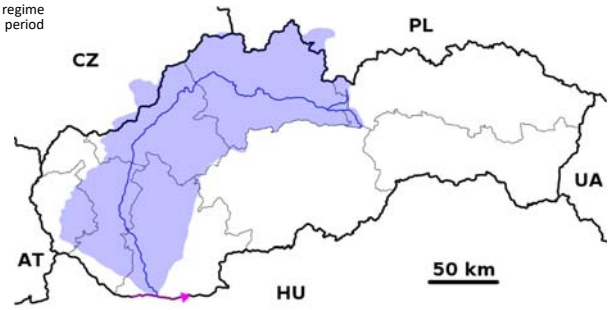
Abstract

The aim of this study was to detect and analyse changes in the mean monthly discharges on six selected gauging stations in the Vah River basin on the territory of Slovakia. We have been looking for changes in the regimes and flow characteristics of mean monthly discharges between the periods 1961-2000 and 2001-2015. The analysis consists of the seasonal detection of the occurrence of extreme minimum and maximum mean monthly discharges as well as looking for significant increasing and decreasing of trends within both periods. Finally, we have detected changes in the occurrence of extremely low mean monthly discharges by looking at monthly low flows lower than Q355d in all the gauging stations analysed. Although all the results are station oriented, we can conclude that the flow regime along the Vah River basin has changed; we can see a higher concentration of extremes in the given months and conclude that the period 2001-2015 shows an increase of months with extremely low mean monthly flows in some stations.

Table 1 List of selected gauging stations in the Váh River basin

ID nr.	River Basin	Gauging Station	River	River km	River basin area [km²]	Elevat [m.a.s
5400	Váh	Podbanské	Belá	21,35	93,49	922,
5550		Liptovský Mikuláš	Váh	346,60	1107,21	567,(
5840		Trstená	Oravica	4,25	129,56	589,4
6130		Martin	Turiec	6,90	827,00	389,8
6180		Čadca	Kysuca	29,20	492,54	408,3
6400		Dohňany	Biela voda	4,00	163,17	284,8



The data used at all the stations consists of mean monthly discharges from the period of observation of 1961-2015. This period was subsequently divided into two parts, i.e., the actually valid reference period of 1961-2000 and 2001-2015. The aim of the study was an analysis of changes in the regimes and flow characteristics of the mean monthly discharges. First, the detection of the changes in the seasonal occurrence of extreme minimum and maximum mean monthly discharges was performed. For the trend analysis, the Mann-Kendall Test method (Kendall, 1975), were used. Then, we tried to detect the driest periods of mean monthly discharges by looking at changes in the occurrence of mean monthly flows lower than Q_{355} in all the gauging stations analysed

Seasonality and trend analysis with percentage of minimum and maximum mean monthly discharges occurrence

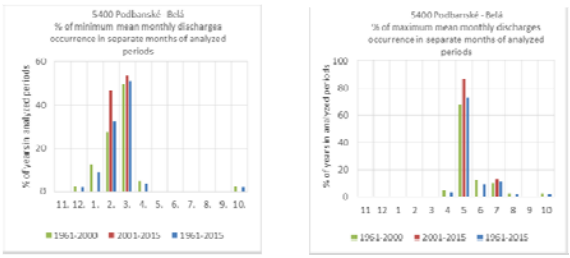


Figure 1. The percentage of the occurrence of minimum and maximum mean monthly discharges in the months and periods of observation analysed at the Podbanské-Belá station

We can conclude for the Váh River basin that during the period of 2001-2015, minimum and maximum discharges have been concentrated into fewer months than in the 1961-2000 period. The highest concentration of maximum mean monthly discharges during both periods in the upper Váh region was in May, due to snowmelt floods with an origin in the High Tatras region. At the Belá – Podbanské gauging station, the shift of the maxima is only to May (and asmall part to July) during the 2001-2015 period, in comparison to some occurrences in April and June in the reference period. We can see some shifts to earlier months in some stations when looking at the frequency of occurences of maximum mean monthly discharges along the Váh River basin; e.g., in the Turiec River basin a partial shift from April to March in the Biela Voda - Dohňany gauging station from March to January. These shifts may be caused due to the lower elevation zones of the Váh River sub-basins and rising temperatures, which have caused earlier snowmelts during recent decades. At these stations there is a lower percentage of the maximum mean monthly discharges occurring in July (which is a month typical for flash floods in Slovakia) in comparison to the 1961-2000 period, while in the rest of the stations evaluated, we can see a slight increase in July in the occurrence of maximum mean monthly discharges Concerning the occurrence of minimum mean monthly discharges, some shifts can be observed for the period 2001-2015 as well; i.e., in the months of February to December at the headwaters of the Váh River basin, and from the winter months to the summer and autumn months for the stations located in the middle and lower parts of the basin. In general, the minimum values are more concentrated in fewer months than in the reference period of 1961-2000, where the dispersions of occurrences are more significant.

The trend analysis of mean monthly discharges along the Váh River basin shows that although we can observe decreasing or increasing trends in discharges, they are, in most cases, insignificant, see Table 2. In general, the significant trends confirm changes indicating the shifts of high-flow periods from spring towards winter and low-flow periods from summer towards later in the autumn.

Table 2 Vah River Basin results for Mann-Kendall trend testing of mean monthly discharges

ID	period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
5400	1961-2015	-	-	-	+	+	-	-	-	+	-	+	+
	1961-2000	-	-	-	-	+	+	-	-	+	+	+	+
	2001-2015	+	+	+	-	+	+	+	+	+	+	+	+
5550	1961-2015	+	+	+	-	-	-	-	-	-	-	-	-
	1961-2000	-	-	-	-	-	-	-	-	+	-	-	-
	2001-2015	+	+	-	-	-	+	+	+	+	-	-	-
5840	1961-2015	-	-	+	-	-	-	-	-	-	-	-	-
	1961-2000	-	-	-	-	-	-	-	-	-	-	-	-
	2001-2015	+	+	-	-	-	-	+	+	+	+	+	+
6130	1961-2015	+	+	+	-	-	-	-	-	-	-	-	-
	1961-2000	+	-	-	-	-	-	-	-	-	-	-	-
	2001-2015	+	+	-	-	-	-	-	+	-	-	-	+
6180	1961-2015	+	+	-	-	-	-	-	-	-	+	+	-
	1961-2000	+	+	-	-	-	-	-	-	+	+	+	+
	2001-2015	+	+	-	-	-	-	+	+	+	+	+	+
6400	1961-2015	+	-	-	-	-	-	-	-	-	-	-	-
	1961-2000	-	-	-	-	-	-	-	-	+	-	-	-
	2001-2015	+	+	-	-	-	-	+	+	+	-	+	+

Materials and methods

The 19,696 km² Váh River basin is the largest river basin in Slovakia. In the course of over a year, the Váh River, whose river network has a length of almost 16,000 km, will drive up to 5.4 billion m³ of water. Coming from the northern mountain region to the lowlands in the south of Slovakia, this basin covers different runoff regimes. A total of six gauging stations were selected for the analysis, see Table 1
The data used at all the stations consists of mean monthly discharges from the period of observation of 1961-2015. This period was subsequently divided into two parts, i.e., the actually valid reference period of 1961-2000 and 2001-2015. The aim of the study was an analysis of changes in the regimes and flow characteristics of the mean monthly discharges. First, the detection of the changes in the seasonal occurrence of extreme minimum and maximum mean monthly discharges was performed. For the trend analysis, the Mann-Kendall Test method (Kendall, 1975), were used. Then, we tried to detect the driest periods of mean monthly discharges by looking at changes in the occurrence of mean monthly flows lower than Q_{355} in all the gauging stations analysed.

Detection of number of dry years, with mean monthly discharges Q_{355}- Q_{364}

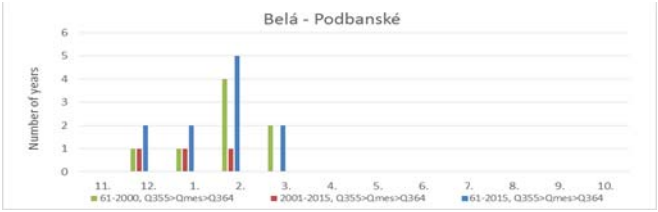


Figure 2 Bela-Podbanske station number of dry years

Finally, looked at the occurrence of mean monthly discharges lower than the Q_{355d} discharges in the periods and months analysed. Figure 2 presents an example of the analysis in the Podbanské-Belá gauging station from1961-2000. The dry months are indicated from December to March, while in the 2001-2015 period, they were only from December to February. This finding is similar to the analysis at the Liptovský Mikuláš station, but also includes September as a month with occurences of low mean monthly flows. For example, in the Turiec River basin there were no monthly flows below Q_{355d} observed during the last period of 2001-2015. The occurrence of such extremely low monthly flows in the lower part of the Váh River basin was recorded in the summer-autumn months, especially from August till November. This is in line with the conclusions of Poórová et al. (2019), confirming the increasing occurrence of low-flow months in the period 2001-2015 comparing with reference period in Slovakia, whose changes were more visible in the middle and southern parts of Slovakia

Conclusions

Although the results are oriented toward the gauging stations, the results suggest that the mean monthly discharge regime along the Vah River basin has changed in the last period of 15 years compared with the reference period of 1961-2000. The density of the concentration of the maximum and minimum mean monthly discharges in the given months of the 2001-2015 period is visible in all the stations analysed. Although the trend analysis did not show much significance in the mean monthly discharges, we can see that in the 2001-2015 period, there were some changes in trends in the mean monthly discharges in comparison to the previous 1961-2000 period, indicating a shift in the minimum and maximum monthly flows. Finally, the results show the importance of our preparedness for the impact of climate change on global runoff regimes, water resources, and landscapes.