Futures changes of short-term rainfall in Slovakia

Silvia Kohnová and Gabriel Földes

Slovak University of Technology, Faculty of Civil Engineering, Department of Land and Water Resources Management, Bratislava, Slovakia

Abstract

This study focused on the impact of climate change on the characteristics and design values of short-term rainfall intensities in selected stations of Slovakia. To simulate future rainfall data in hourly time step, the Community Land Model (CLM 4.0.) was used (http://www.cgd.ucar.edu/tss/clm/). The CLM scenario was simulated by the IPCC scenario for A1B for the 21st century; the scenario is semi pessimistic with a 2.9°C increase in the global temperature by 2100. Together, 31 climatological stations from the whole territory of Slovakia were selected. The hourly short-term rainfall intensities were divided into three time periods: historical–observed data (1961-2020), the near future (2031-2070), and the far future (2071-2100) climate scenario data. First, the analysis of data homogeneity, trends, and breaking points, and the seasonality of extreme rainfall events in all durations from 60minutes up to one day and for all selected periods were performed. The results show an increasing insignificant trend at most climatological stations; the seasonality of maximum rainfall events revealed the future changes compared to the historical period, and the shifts in extreme rainfall occurrence between the historical and future periods are to a later date almost in summer months. The simple scaling theory was adopted to estimate the IDF curves of short-term rainfall. Where the scaling exponents also confirm their future changes with higher values compared to the historical period. Finally the design values of short-duration rainfall have been estimated having also an increasing character for the future.

MOTIVATION

The aim of the study is the detection of historical and future changes in short-term precipitation totals and their characteristics in Slovakia. This work consists of the analysis of historical and simulated time series, focused on the analysis of trends, seasonality, breaking points, and changes in the characteristics of the intensities of short-term rainfall lasting from 60 min. to 1 day. To detect changes in design values of short-term rain intensities, important especially in engineering hydrology, we will apply procedures based on the methodology of simple scaling.

The following steps were foreseen:

- Processing input data of minute short-term rainfall totals from 31 climatological stations in Slovakia to calculate the intensities of short-term rainfall totals for durations of 60, 120, 180, 240 and 1440 min.
- The selection of a suitable CLM scenario for testing the outputs of climate characteristics from regional climate models until 2100.
- Analysis of changes in the characteristics of short-term rainfall totals, such as trends, seasonality indices, break points, etc. were performed for selected scenario historical and two future periods.
- Estimation of scaling exponents and detection of historical and future changes for all analyzed climatological stations for the warm half-year and selected periods of observation series.
- Estimation of design rainfall totals using scaling exponents and detecting changes in the design of short-term rainfall.
- Detection of factors influencing changes in design values of short-term rain intensities within the analyzed territory.

INPUT DATA

The input data consisted of hourly precipitation total simulated by CLM scenario data from 1961 to 2100. Three time periods were chosen for the analysis as follows:

- a historical period of 60 years from 1961 to 2020
- a near future period of 40 years from 2031 to 2070
- the distant future period of 30 years from 2071 to 2100.

In each selected period, the analysis was performed on selected rain durations of 60-, 120-, 180-, 240- and 1440-minutes duration in the warm half-year (April-October). The Slovak Hydrometeorological Institute in Bratislava (SHMÚ) provided historical data from 31 climatological stations across the entire territory of Slovakia, shown in Fig. no. 1.

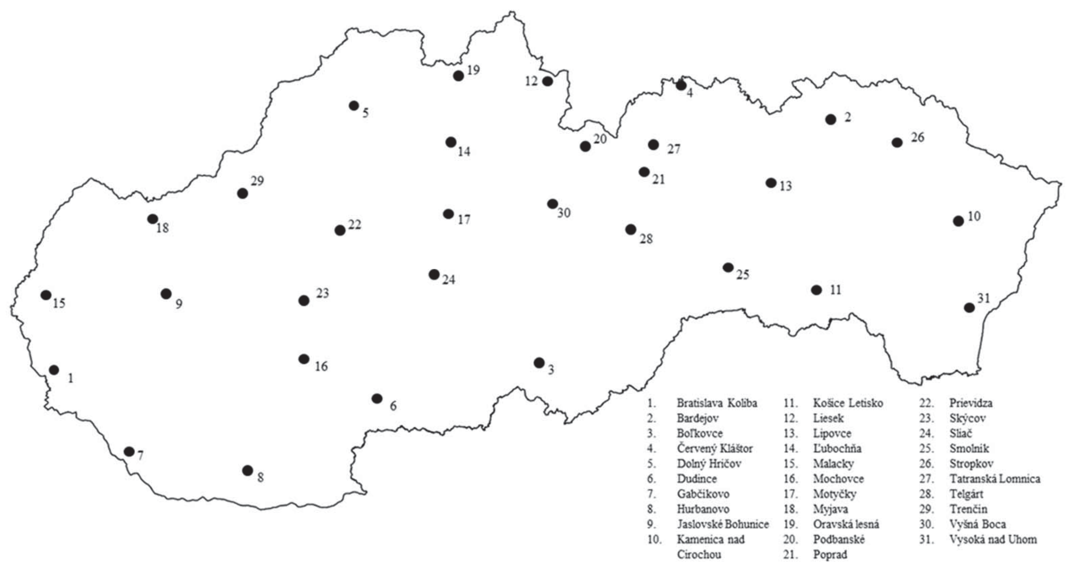

Fig. 1 – Location of selected climatological stations on the territory of Slovakia.

TREND ANALYSIS

The detection of trends in short-term rainfall is an important part of the analysis of the changes in rainfall characteristics in the future. The Mann-Kendall trend test was used here for trend detection.

Trends for the future have an increasing character in most analyzed climatological stations. Significant trends at the significance level of 90% with an increasing tendency were detected at the stations Bratislava-Koliba (Tab.1), Bolíkovce, Červený Kláštor, Hurbanovo, Liesek, Lipovce, Ľubochňa, Smolník, Tatranská Lomnica and Telgárt.

Tab. 1 – Example of the trend analysis in Bratislava-Koliba station

No.	Station	Period/ duration (min)	60	120	180	240	1440
1	BA - Koliba	1961-2020	↘	↘	↗	↗	↗
		2031-2070	↘	↘	↘	↘	↘
		2071-2100	↗	↗	↗	↗	↘

It can be concluded that, especially in the areas of southwestern and eastern Slovakia, there is an assumption of an increasing trend in short-term rainfall, especially in durations from 60 to 240 minutes in the future. Fig. 2 shows the output of results for a 180 minute duration for the far future period 2071-2100. The results also show an increasing trend at most of the analyzed stations in the period of the near future (2031-2070) to a greater extent than in the case of the period of the far future (2071- 2100) where the detected changes in trends were regionally different and growing trends were detected in the territory western and in the north of eastern Slovakia.

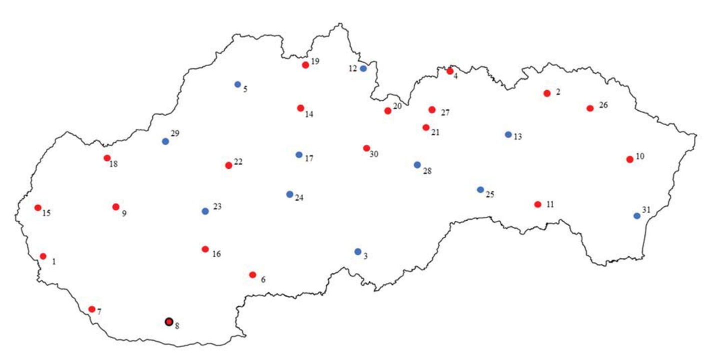

Fig. 2 – Trend analysis for short term rainfall of 180 min for the period of far future (2071-2100).

Legend :blue- decreasing, red increasing trend

SEASONALITY ANALYSIS

The analysis of the seasonality of the occurrence of maximum short-term rains was carried out to detect changes in the occurrence of extremes to future periods during the warm half-year. The Burn vector methodology was used in the analysis. The results of the analysis of changes in the occurrence shifts of maximum short-term rain totals between historical (1961-2020) and future periods (near 2031-2070 and far 2071-2100) are interpreted in Fig. 3 for the far future (2071-2100). The predominant shift in all durations of short-term rains between occurrences is the shift of maximum precipitation totals to a later date in the month from the detected occurrence for the historical period (1961-2020). The analysis shows no significant difference between the two future periods, changes in displacements occur only at four stations.

The maximum shifts in the short-term rainfall occurrences between the future and the historical periods were detected at the stations Červený Kláštor, Dolný Hričov, Hurbanovo, Jaslovské Bohunice and Mochovce, in Fig. 4. The lowest changes in the occurrence of maximum short-term rain totals between future periods and the historical period were detected at the stations Bardejov, Kamenica nad Cirochou, Košice airport, Lipovce, Ľubochňa and Tatranská Lomnica.

Fig. 4 – Changes in the occurrence shifts in days of maximum short-term rainfall between historical (1961-2020) and far future periods (2071-2100) .

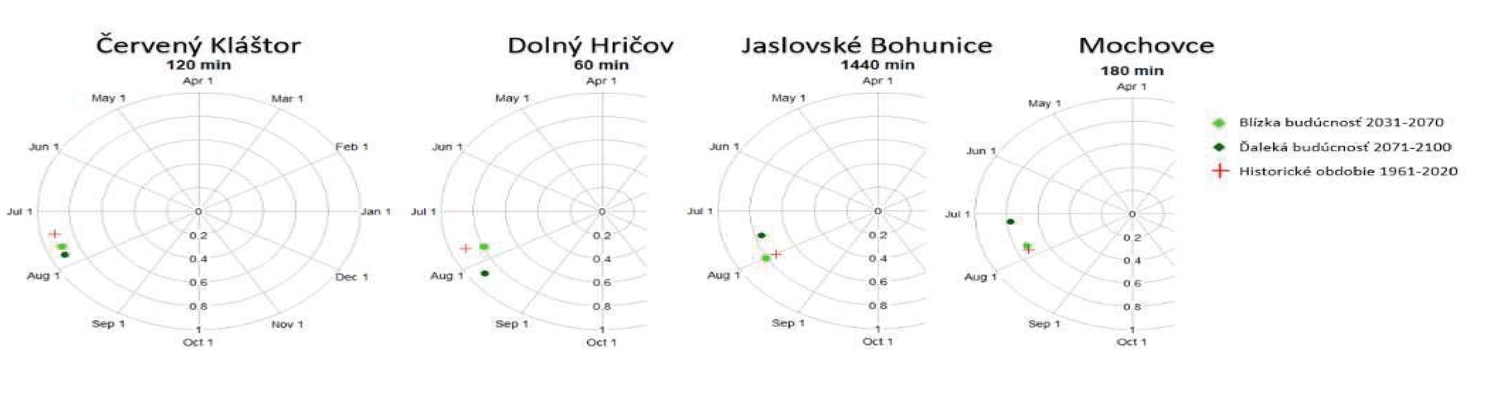

Fig. 4 – Climatological stations with the significant differences in the occurence of the maximum rainfall intensities between the historical (1961-2020) near future (2031-2070) and far future periods (2071-2100).

DESIGN VALUE ESTIMATION

Scaling exponents of short-term rainfall were derived at all the analyzed climatological stations for three periods and the entire warm half-year. Using the derived exponents, the design values of rainfall intensities were scaled to shorter durations than 60 minutes. Scaling exponents were derived using the simple scaling method of statistical moments. The values of the scaling exponents range from 0.45 to 0.8.

Tab.2 – Derived scaling exponents for selected stations

	Scaling exponents		
	1961-2020	2031-2070	2071-2100
BA-Koliba	0.5675	0.6503	0.7627
Bardejov	0.5943	0.4964	0.5857
Boľkovce	0.6726	0.5834	0.634
Dudince	0.6117	0.7566	0.6797
Gabčíkovo	0.6227	0.6413	0.684
Hurbanovo	0.5995	0.6485	0.6301
Jasl Bohunice	0.5781	0.7208	0.6484
Telgárt	0.5511	0.6299	0.5628
KE-Letisko	0.6498	0.5593	0.6427
Trenčín	0.5698	0.6701	0.6038
Lipovce	0.6619	0.6176	0.6452
Ľubochňa	0.6342	0.526	0.5664
Malacky	0.5878	0.6329	0.7442
Mochovce	0.5603	0.6957	0.6494

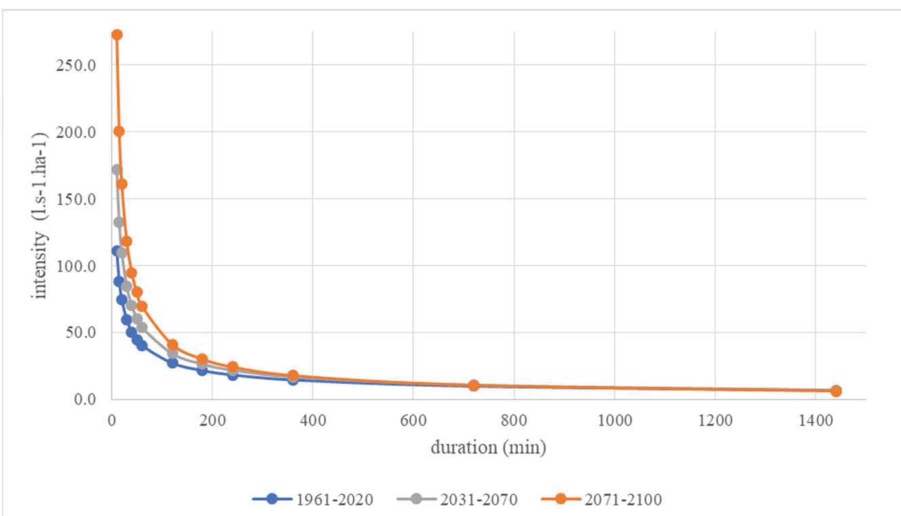

Fig.5 – Comparison of IDF curves for slelected periods analysed with the return periof of 10 years in the Bratislava-Koliba climatological station.

On the basis of the derived design values, the IDF curves were constructed for the return period of 10 and 100 years, Fig. 5.

CONCLUSION

The results showed that climate change, represented by the CLM scenario, will affect the characteristics and the design values of short-term rainfall intensities in the future. This will significantly impact water structures and the need to re-evaluate their safety. The findings of this study also indicate the need to revise urban design guidelines to be prepared for future extreme rainfall events.

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