

Statistical trends of precipitation in chosen climatic station in Slovakia and Libya

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Abstract: - This paper deals with the research of monthly precipitation trends in climatic stations in Libya and Slovakia. The non-parametric Mann-Kendall statistic test was applied to detect trends and to assess the significance of the trends in the time series. The evaluation was done for the time period from November to October. Trend analysis of rainfall data series for 1970–2010 did not show any clear trend for Libya as a whole although mainly decrease in precipitation was proved. It is clear that slight climatic changes may have affected the magnitude and timing of the precipitation within the study area. High statistically significant negative values appear in November and high statistically significant positive values appear in January. Trends analysis in precipitation data in eastern Slovakia was carried out in the time period 1981–2010. Data used in the present study were acquired from Slovak Hydrometeorological Institute. Almost all the gauging stations in Slovakia show positive trend of monthly precipitation. The increase of precipitation – significant positive trend – was proved in stations Turňa nad Bodvou, Mníšek nad Hnilcom, Veľký Folkmár. Significant positive trend in precipitation is proved in July. Decreasing trend is demonstrated only in March.

Key-Words: - Climatic stations, Libya, Mann-Kendall test, monthly precipitation data, Slovakia

1 Introduction

Trend analysis for meteorological and hydrological time series is an important and popular tool for better understanding the effects of climate variation [1]. In the context of global warming; it is a well-known fact that there is an increase in precipitation in middle latitudes. It is gradually becoming more difficult to characterize climatic trends. Data show that there may be different results depending on the study zones [2]. The rainfall of a certain place depends upon many factors and some weather conditions [3], [4], [5], [6]. These include latitude, altitude, topography, and distance from water bodies or other wet areas [7]. The relationship between elevation and precipitation is complex and highly variable in space [8]. Nevertheless, in general, precipitation increases with elevation, mainly because of the orographic effect of mountainous terrain [9], [10]. Thus, it is interesting to study climatic changes in recent precipitation series, especially if we can have a network of rainfall stations with reliable precipitation series.

The statistical analysis of meteorological and hydrological time series is performed with goal to know the trends in space and time distribution of rainfall which helps to reduce the impacts of droughts and floods. Droughts is the most complex but least understood of all natural hazards. It is broadly defined as "severe water shortage". Floods cause huge mainly material damages [11], [12]. Mentioned natural hazards cause loss of life, human and animal suffering and damage to economy and environment. The present study areas are prone to extreme climate events such as drought and flood.

Climatic change is considered likely to increase runoff in the higher latitude regions because of increased precipitation on the other hand flood frequencies are expected to change also in some locations and the severity of drought events could increase as a result of those changes in both precipitation and evaporation. In all these considerations 'the issue' then becomes the effect of global warming and its impacts on the environment and water resources in particular. The Intergovernmental Panel on Climate Change [13], [14] provides a comprehensive review of the potential impacts on climate. IPCC studies suggests an increase in the probability of occurrence of more frequent droughts, as well as floods, in the Atlantic Ocean and Caribbean Sea, the Mediterranean Sea, and the Indian and Pacific Oceans. Observations show that changes are occurring in the amount, intensity, frequency and type of precipitation. Pronounced long-term trends from 1900 to 2005

have been observed in precipitation amount in some places: significantly wetter in eastern North and South America, northern Europe and northern and central Asia, but drier in the Sahel, southern Africa, the Mediterranean and southern Asia.

Several studies have given a great deal of attention to the potential impacts of climatic change and variability in several fields at international level.

A number of studies have been published focusing on the evolution of precipitation, drought conditions and moisture availability in the Mediterranean during the 20th century e.g. [2], [5], [6], [15], [16], [17], [18]. Hydrological time series and rainfall distribution in Slovakia has been investigated in [5], [6], [19], [20], [21] and [22]. The detection of trends in meteorological data, in particular rainfall is essential for the assessment of the impacts of climate variability and change on the water resources of a region [23], [24]. The Mann-Kendall test is example of non-parametric tests that are applied for the detection of trends in many studies and is widely used in hydrology science [1], [7], [8], [15], [16], [17], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36] and many others.

2 Material and methods

2.1 Study area

Libya is situated in North Africa between Egypt and Algeria, with the Mediterranean to the north and Chad and Niger on its southern borders. Apart from the coastal strip and the mountains in the south, it is desert or semi desert. North of Libya is influenced by Mediterranean depressions during winter season as a result of its geographical location, most of the precipitation falls as showers that produced from cumuliform clouds which moved along the coastal line. Rainfall averages ranged in these areas (north of Libya) from about 200 to 500 mm, with a maximum of recording on the regions of Jabal Al Akhdar "the Eastern Highlands" where was about 850 mm, and to about 750 mm on Jabal Nafusah areas "Western Highlands" [18]. The climate is Mediterranean along the coast and dry extreme desert is in the interior part of the country.

Monthly rainfall data recorded at 17 stations operated by Libya's Meteorological Service with data length from 1971 to 2010 were collected for this study. In all, a network stations (Table I) and 40 years of data were set up to study precipitation trend in Libya.

The territory under this study in Slovakia lies in the eastern part of the country, particularly in the Bodrog and Hornád river basins. The morphological type of terrain in the Hornád valley is dominated by rolling hills, higher and lower uplands. The southern sub-basin is part of a plain and the Slovakian Karst and is formed by moderately higher uplands [27]. The Bodrog river valley has varied climatic conditions. Precipitations are highly differentiated. The highest annual totals are mainly in the eastern border mountains and Vihorlat where rainfall totals are about 1000 mm. Decrease in total precipitation is quite marked directly to the south, where annual totals fall to below 800 mm. The Michalovce, Lastomír and Medzibodrožie lowlands rank among the driest in the eastern region (550 mm rainfall per year) [11].

Monthly precipitation data recorded at 20 stations operated by Slovak Hydrometeorological Institute with data length from 1981 to 2010 were collected for this study. Geographical location of stations is listed in Table II. 30 years of data were set up to study precipitation trend in the east part of Slovakia.

2.2 Statistical analysis

Many tests for the detection of significant trends in meteorologic time series can be classified as parametric and non-parametric methods. The Mann-Kendall (MK) test Kendall [37]; Mann [38] is a rank-based nonparametric test for assessing the significance of a trend, and has been widely used in hydro-meteorological trend detection in many studies.

In this study non-parametric Mann-Kendall test is used for the detection of the trend in a time series. Mann-Kendall test [37], [38] is following statistics based on standard normal distribution (Z), by using Eq.(1).

$$Z = \begin{cases} \frac{S - 1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S + 1}{\sqrt{Var(S)}} & \text{if } S < 0 \end{cases} \quad (1)$$

$$S = \sum_{k=1}^{n-1} \sum_{k+i}^n \text{sgn}(x_j - x_k) \quad (2)$$

$$\text{sgn}(x_j - x_k) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \quad (3)$$

$$Var(S) = \left[n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5) \right] / 18 \quad (4)$$

where n is the number of data points, m is the number of tied groups (a set of sample data having the same value).

According to this test, the null hypothesis H_0 states that the depersonalized data (x_1, \dots, x_n) is a sample of n independent and identically distributed random variables. The alternative hypothesis H_1 of a two-sided test is that the distributions of x_k and x_j are not identical for all $k, j \leq n$ with $k \neq j$. The significance level is chosen as $\alpha = 0.05$ and $Z_{\alpha/2}$ is the value of normal distribution function, in this case $Z_{\alpha/2} = 1.95996$. Hypothesis H_0 - no trend is if ($Z < Z_{\alpha/2}$) and H_1 - there is a trend if $Z > Z_{\alpha/2}$. Positive values of Z indicate increasing trends, while negative values of Z show decreasing trends.

The magnitude of the trend was determined using Sen's estimator. Sen's method assumes a linear trend in the time series and has been widely used for determining the magnitude of trend in hydro-meteorological time series [39], etc.. In this method, the slopes (β) of all data pairs are first calculated by

$$\beta = \text{Median}((x_j - x_k) / (j - k)) \quad (5)$$

for $i = 1, 2, \dots, N$, where x_j and x_k are data values at time j and k ($j > k$), respectively and N is a number of all pairs x_j and x_k . A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

3 Results and discussion

The results of statistical analysis of precipitation in chosen climatic station in Libya and Slovakia are discussed in the following.

The evaluation was done for the time period from November to October. Data series for 40 years period in Lybia and for 30 years period in Slovakia was considered for trend detection. Monthly rainfall data were analyzed by basic statistical methods for evaluated periods. The trend was proved by nonparametric Mann Kendall test. In the Sen's method the slope of all the data points are calculated and their median value is the Sen's estimator of slope which determines magnitude of the trend.

Statistical analyses of precipitation are presented for monthly data for stations in Libya at Figures 1, 2, 3 and 4 and in Table I.

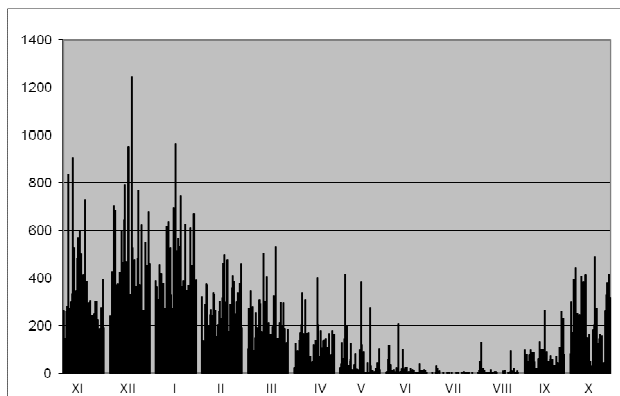


Fig. 1 Monthly precipitation in climatic stations in Libya

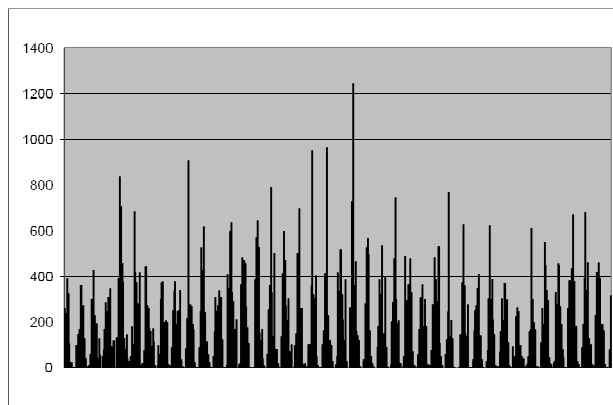


Fig. 4 Precipitation in Libya during period 1971-2010

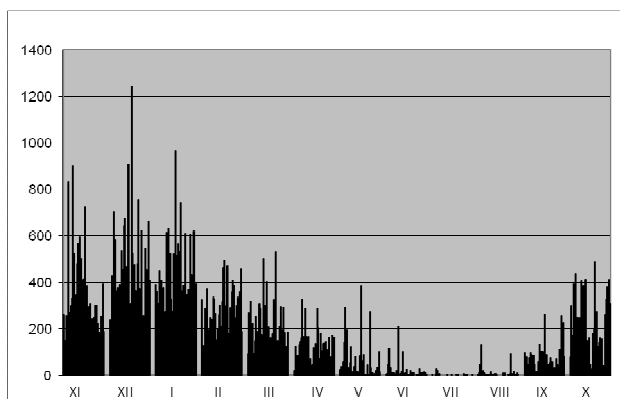


Fig. 2 Monthly precipitation in Libya in stations near the sea

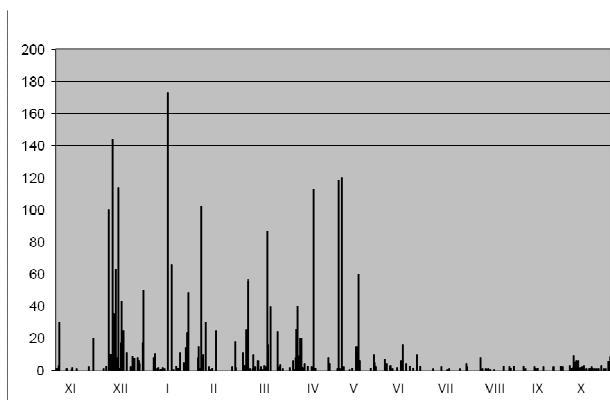


Fig. 3 Monthly precipitation in Libya in stations in the desert

The distribution of the monthly precipitation presents Figures 1-3 (in mm). It is clear that the highest rainfall is in the winter in months from October to March. It is interesting to divide climatic stations in Libya to two groups – stations near the sea and stations in the desert, as there are big differences in the amount of rainfall. Precipitation in the stations near the sea varies about 300 mm and maximum is about 1200 mm. The distribution of precipitation in these stations (Fig. 2) is almost the same as in the whole Libya (Fig. 1). Amount of the rainfall in the desert is about 50 mm; maximum is 170 mm in the desert stations (Fig. 3).

Table I Sen's estimator for monthly precipitation in Libya

Station	Month					
	XI	XII	I	II	III	IV
Nalut	-0	+0	0,021	-0	-0,038	-0,067
Garyan	-0,388	-0	0,251	0,064	-0	0,177
Misurata	0,163	0,66	0,588	0,214	-0,125	+0
Sorman	-0,615	0,595	0,309	0,12	0,235	+0
Benina	-0,473	0,076	0,194	-0,333	-0,065	-0
Derna	-0	0,228	0,27	0,394	0,111	0,142
Zuwarah	-0,321	-0,35	0,263	-0,292	-0,196	-0
Al Jaghbub	-0	-0	-0	-0	-0	-0,009
Ghadames	-0	-0	+0	-0	-0	-0
Sabha	-0	+0	+0	-0	-0	-0
Ajdabiya	0,025	-0	0,273	-0,011	-0	+0
Homs	-0,632	0,385	0,667	0,117	0,149	-0,1
Syrta	0,046	0,143	0,782	0,374	-0,111	0
Shahat	0,421	1,4	0,71	1,25	0,417	0,154
Ghat	-0	0	0	0	0	0
Al Kufrah	-0	-0	-0	-0	-0	-0
Jalu	+0	+0	+0	+0	+0	+0
Station	Month					
	V	VI	VII	VIII	IX	X
Nalut	-0	-0	-0	-0	-0	-0
Garyan	-0	+0	-0	+0	-0	0,1
Misurata	-0	+0	+0	0,008	+0	-0,067
Sorman	-1E-18	-0	-0	-0	-0	-0,095
Benina	+0	-0	-0	-0,17	-0	-0,053
Derna	-0	-0	-0	-0	-0	-0
Zuwarah	+0	+0	-0	-0	0,02	-0,208
Al Jaghbub	-0	-0	-0	-0	-0	-0
Ghadames	-0	-0	+0	-0	-0	-0
Sabha	+0	0	0	0	0	+0
Ajdabiya	-0,011	-0	+0	-0	-0	-0,091
Homs	+0	+0	0	-0	0,034	-0,091
Syrta	0	-0	-0	0	-0,007	0
Shahat	0,026	-0	-0	-0	0,003	0,524
Ghat	-0	-0	0	-0	-0	-0
Al Kufrah	+0	-0	+0	+0	+0	+0
Jalu	0,003	0	0	-0,033	0,009	0,016

Figure 4 presents the distribution of precipitation during the period from 1971 to 2010. From this figure is not obvious any trend in rainfall in Libya.

The results from statistical nonparametric Mann Kendall test of precipitation in Libya are in Table I. Statistically significant trends are in bold. Regarding trend analysis of monthly precipitation data (Fig. 4, Table I) there is no clear trend. No trend was proved in the stations situated mostly in the desert – Al Jaghub, Ghadames, Sabha, Ghat, Al Kufrah, Jalu (marked in grey in Table I). There is no or very small values of rainfall in general. Declining trend was demonstrated in the stations Nalut, Sorman, Benina and Zuwarah. In the stations Sorman, Benina and Zuwarah the Sen's estimator is statistically significant for two months. High statistically significant negative values appear in November. In the stations Homs, Syrta Shahat and Derna the rising trend in rainfall time series was demonstrated. The value of the Sen's estimator is statistically significant for two months in Syrta and Derna, for four months in Homs and for six months in Shahat. Large statistically significant positive values of the Sen's estimator in these stations were in January. Positive and negative values were evenly balanced and no or only for one month statistically significant trend was proved in stations Garyan, Misurata and Ajdabiya.

Statistical analyses of precipitation in Slovakia are presented for monthly data at Figure 5 and 6 and in Table II.

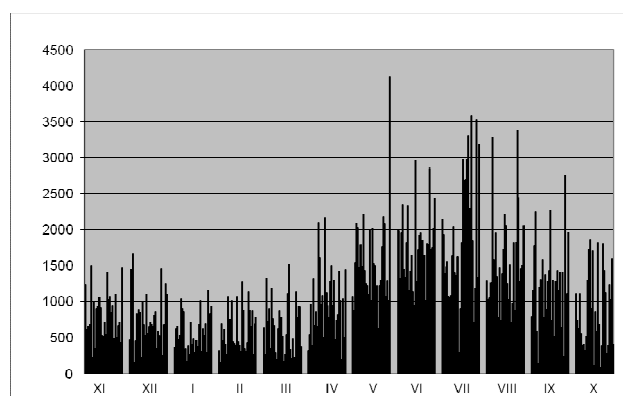


Fig. 5 Monthly precipitation in climatic stations in Slovakia

The distribution of the monthly precipitation in chosen climatic stations presents Figures 5 (in mm). The highest rainfall is opposite to Libya and is in the summer time in months from April to September. Precipitation varies about 900 mm and maximum is about 3600 mm what is two times more than in Libya.

Although Slovakia is heterogeneous country with mountains as well as lowlands the area no big

differences in amount of precipitation were proved. The area of Slovakia is much smaller than that of Libya so the stations were not divided to two groups as in Libya.

Table II Sen's estimator for monthly precipitation in Slovakia

Station	Month					
	XI	XII	I	II	III	IV
Veľké Kapušany	0,377	0,23	0,245	0,913	-0,08	0,04
Humenné	0,071	-0,22	0,13	0,269	-0,47	0
Michalovce	0,067	0,217	0,236	0,505	-0,06	0,338
Snina	0,557	-0,37	-0,21	0,1	-0,33	-0,088
Svidník	0,092	-0,67	0,094	0,3	-0,05	0,66
Tisinec	0,059	-0,6	0,1	0,236	-0,04	0,289
Horovce	0,329	0,222	0,28	1,25	0,286	0,389
Bardejov	-0,03	-0,61	0,518	0,089	-0,03	0,05
Hanušovce	-0,46	0,067	0,441	0,257	-0,13	0,52
Moldava n/Bodvou	-0,46	0,6	0,332	0,317	-0,31	0,288
Turňa n/Bodvou	0,095	0,557	0,595	0,514	-0,14	0,808
Spišská Nová Ves	-0,32	0,35	0,58	0,027	-0,04	0,568
Spišské Vlachy	-0,4	0,138	0,417	0,267	0,15	0,2855
Kysak	-0,23	0,543	0,133	0,143	-0,42	-0,733
Čaňa	0,125	0,089	0,4	0,481	-0,46	0,368
Mníšek n/Hnilcom	0,63	0,643	0,8	0,4	0,075	0,973
Veľký Folkmár	0,413	0,467	0,638	0,25	0,057	0,46
Jakubovany	-0,34	-0,66	0,255	0,153	-0,02	0,54
Vyšný Čaj	0,425	-0,08	0,47	0,457	-0,29	0,209
Chmeľnica	0,487	-0,56	0,248	0,531	0,66	0,256

Station	Month					
	V	VI	VII	VIII	IX	X
Veľké Kapušany	0,043	-0,162	0,7	1,393	0,765	0,254
Humenné	0,3	-0,25	0,807	0,55	0,474	-0,143
Michalovce	1,03	0,33	0,62	-0,04	0,41	-0,281
Snina	-0,02	-0,6	1,075	0,5	0,053	0,127
Svidník	0,258	0,613	3,248	0,111	-0,27	0,246
Tisinec	0,425	0,7	2,2	0,755	0,393	0,273
Horovce	1	0,664	1,08	-0,439	0,559	-0,108
Bardejov	0,414	0,457	2,47	0,314	-0,04	0,4
Hanušovce	-0,12	-0,1	1,189	0,64	0,386	-0,255
Moldava n/Bodvou	-0,66	-0,067	1,7	0,54	0,365	-0,292
Turňa n/Bodvou	-0,63	0,525	2,21	0,67	0,429	-0,038
Spišská Nová Ves	-0,26	0,583	2,676	1,157143	0,268	0,46
Spišské Vlachy	-0,25	0,856	4,052	1,275	0,718	0,39
Kysak	-0,2	-0,243	2,3	0,214286	1,138	-0,11
Čaňa	0,685	0,745	1,47	0,1	0,747	0,033
Mníšek n/Hnilcom	-0,44	1,864	3,511	1,25	0,914	0,473
Veľký Folkmár	-0,27	0,593333	2,74	0,867	0,969	0,374
Jakubovany	-0,33	0,4	1,692	0,856	0,306	0,4
Vyšný Čaj	0,23	0,188	1,687	-0,062	0,281	0,07
Chmeľnica	0,042	1,12	1,9	1,072	0,305	0,883

Figure 6 presents the distribution of precipitation in chosen stations in Slovakia during the assessed period from 1981 to 2010. From this figure is obvious slightly increasing trend in rainfall which was proved also by statistical nonparametric Mann Kendall test (Table II).

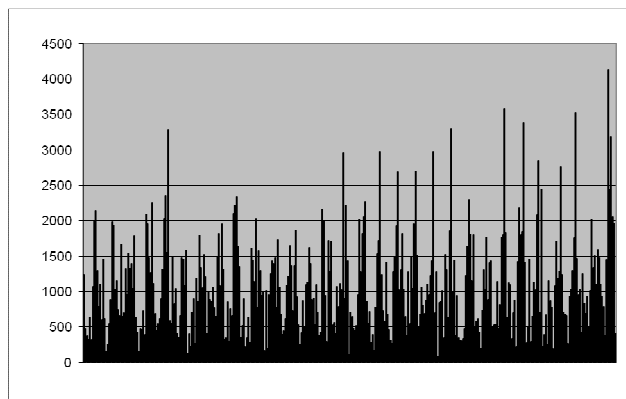


Fig. 6 Precipitation in Slovakia during period 1981-2010

Rainfall trends show variability in magnitude and direction of trend from one station to another. It depends upon many factors, e.g. latitude, altitude. Statistically significant trends are also in bold. Significant positive trend is in gauging stations – Veľké Kapušany, Turňa nad Bodvou, Spišská Nová Ves, Spišské Vlachy, Mníšek nad Hnilcom (January, June, July), Veľký Folkmár. Decreasing trend of precipitation was found only in March all other months prove increasing trend of precipitation. The trend slope is increase of annual precipitation e.g. in Mníšek nad Hnilcom it is 0.057 mm/year. In conclusion, trend analysis of rainfall data series for 1981–2010 showed increasing trend in Slovakia.

4 Conclusion

Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, especially at lower latitudes. There are also increases in some regions in the occurrences of both droughts and floods IPCC [13]. Recent studies of climate change have focused mainly on long-term variability of precipitation.

The objective of this study was to investigate precipitation trends in chosen climatic stations in Libya and Slovakia. We investigated 17 climatic stations in Libya and 20 climatic stations in Slovakia. The studied period was from 1971 to 2010 in Libya and from 1981 to 2010 in Slovakia. Monthly precipitation trends were detected by

nonparametric Mann-Kendall statistical test. Negative trends of monthly precipitation were found in the analyzed rainfall gauging stations in Libya. As expected, rainfall trends show large variability in magnitude and direction of trend from one station to another. Monthly rainfall data series show increasing trend for eastern Slovakia's gauging stations. November and August were observed to have the highest decreasing trends in Libya and March in Slovakia. All other month in Slovakia displayed increasing trends. In conclusion, Libya shown decreasing trend and Slovakia has an increasing trend of precipitation time series.

This paper deals with the research of monthly precipitation trends. Statistical analysis of the precipitation data and the non-parametric Mann-Kendall statistic test were applied to detect trends and to assess the significance of the trends in the time series in climatic stations in Libya and Slovakia. The Mann-Kendall test is appropriate for hydrometeorological time series testing and can be widely applied for the detection of trends in climatology and hydrology sciences.

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