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The Analysis of Trend and Cycle Between Rainfall and Discharge in Ghaleroudkhan Basin

[1]Mahmoud Roshani, [1]Mehrdad Ramazanipour, [2]Fatemeh Sotoudeh and [3]Jafar Ghomi Aveily

[1]Department of Geography, Chalous Branch Islamic Azad University, Chalous, Iran
[2]Department of Geography, Zanjan University, Zanjan, Iran
[3]Department of Geology, Chalous Branch Islamic Azad University, Chalous, Iran

Abstract: The type and time and cycle of discharge changes in relation to rainfall in the Ghaleroudkhan basin (Iran) have been analyzed for the period '1966-2002' by applying the Man-Kendal test trend and spectral analysis. The obtained results show that time series had trend and abrupt change in monthly, seasonally and annually scale. Especially the discharge of winter, spring and summer was also seen a significant descending trend. In other words, autumn in relation to other seasons had least gradient in descending trend. In sum, with investigation to obtained diagrams, the trend of tails u_i of rainfall have been identical with discharge during period which is representative of high dependence of discharge changes in relation to rainfall variable. Also, the results of spectral analysis showed that there are non sinus cycles in seasonal scale and non sinus cycles of discharge is more important and found clearer cycles for summer and autumn. The monthly rainfall and discharge cycles are weaker than seasonal cycles. Finally, in rainfall the '2-2.2', '2.7-3.8', '4.2-5.6', '7.7-9.5', '20' year sinus cycles and in discharge the '2-2.4', '2.9-3.8', '7.7-9.5' year sinus cycle are meaningful, respectively.

Key words: Rainfall and discharge · Man-Kendal · Spectral analysis · Fluctuation · Trend · Cycle

INTRODUCTION

Today, the industrial ever-increasing activity can play a significant role in changing the Earth's climate and its effect is specified because of the global warming phenomenon and the type of precipitation. On the other hand, using surface waters increased because of increasing agriculture, industrial activities and population growth. This led to changing of rivers discharge. [1] Brunetti *et al.,* (2000) identified a number of days with negative trend of precipitation by non parametric Man-Kendal test in north of Italy. In addition, they showed that the increase of annual precipitation intensity leads to significant positive trend in relation to the whole heavy precipitation. [2] Buffoni *et al*., (1999) are believed that there are various trends in different seasons and regions and a decreasing trend over the entire Italy annually, but it is statistically meaningful only from center to south. [3] Camuffo (1984) showed that there are fluctuations and periodical trend in the precipitation data series for a period of '256' years (1981 up to 1725) in Padova of Italy. [4] Conway and Hulme (2005) concluded that the runoff of Nile River is sensitive to rainfall fluctuations in recent decades and it alters from a basin to another. [5] Domonkos (2003) showed that there is a clear connection between the trends and large scale climatic changes and reduced the sum of about '15%' up to '20% ' in Hungary during the twentieth century. [8] Marengo (2005) believed, from his study about stream flows variability in the South American, which none of the significant trend is observed in the discharge average of rivers. [9] Partal and Kahya (2006) asserted that there is a significant trend in annual precipitation of January, February and September of Turkey and can be observed a considerable decrease in west and south of annual rainfall especially the Black sea coast. [10] Yue and Hashino (2003) reported that there is not meaningful change in the monthly and annual precipitation in the region II of Japan but it has reduced to '11.8%' in region III and in region IV is seen a meaningful decline in monthly and annual precipitation from September up to February.

This study has focused on northern Iran, as the northern part of the Alborze region is an area where heavy rainfall events are rather frequent and where many disastrous floods have been reported in the last decade. Thus, the primary aim is the study of the rainfall and discharge changes in connection with climatic changes.

Corresponding Author: Mehrdad Ramazanipour, Islamic Azad University, Chalous Branch, Chalous, Iran.
Mob: +98-9111370065.

MARTIAL AND METHODS

Ghaleroudkhan basin is considered as local catchment in Guilan province which is located in west of province and north of Iran as its length is '51' km. The source of this river is Zanjan Mountains that flows with south-north path into Caspian Sea. It is limited between the meridians '327265' 'E' and '361246' 'E' and parallel '4096643"N' and'4141685"N'. The area and circumference of basin are about '461.01' km^{2}and '131.3' km respectively and the altitudes vary from '-33' m to '2831' m. The data of Ghaleroudkhan gauge rain and hydrometric stations are used which were located in the altitude of '200' m from m.s.l (Figure 1).

Methodology: In the Mann-Kendall test, for each element x_i (i =1,... , n) of the series, the number n_i of lower elements x_j ($x_j < x_i$) preceding it ($j < i$) is calculated and the test statistic t is given by $t = \sum_{i=1}^{n} n_i$. In the absence of any trend (null hypothesis), t *is* asymptotically normal, independent from the distribution function of the data and $u(t) = (t - \langle t \rangle) / \sqrt{\operatorname{var}(t)}$ has standard normal distribution, with <t? and variance (t) and given by: $\langle t \rangle / = (n(n-1))/4, \operatorname{var}(t) = (n(n-1))(2n+5)/72$. The null hypothesis can, therefore, be rejected for high values of $|u(t)|$, being the probability '$\acute{a}_1$' of rejecting the null hypothesis, when it is derived by a standard normal distribution table:

$$a_1 = p(|u(t)| > |u(y)|) \tag{1}$$

In the absence of any trend, the graphical representation of the direct (u_i) and the backward (u'_i) series obtained with this method gives curves which overlap several times, whereas, in the case of significant trend, the intersection of the curves enables the detection of the approximate time of occurrence of the phenomenon (Buffoni *et al*., 1999).

In continue, spectral analysis used for calculating of cycles and fluctuation. In this method z_0 $z_1 \ldots$ z_{n-1} is an arbitrary time series of length 'n' the time series can be expressed as the sum of sinusoids at the frequencies of the series:

$$z_t = a_i + \sum_{i=1}^{q} (a_i Cos 2\pi f_i t + b Sin 2\pi f_i t) \tag{2}$$

Where the summation is over Fourier frequencies: $f_i = \frac{i}{n}$. If the length of time series is odd, then the number of harmonics calculates by: $q = \frac{(n-1)}{2}$. 'q' is length of the period and its coefficients is given by:

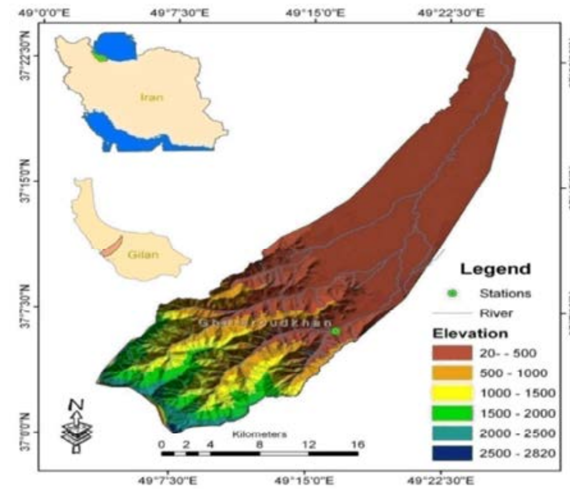

Fig. 1: Geographic location of Ghaleroudkhan basin

$$a_0 = \frac{1}{n} \sum_{i=1}^{n} z_t \bar{z}, a_1 = \frac{2}{n} \sum_{i=1}^{n} z_t Cos 2\pi f_i t$$

and

$$b_i = \frac{2}{n} \sum_{i=1}^{n} z_t Sin 2\pi f_i t$$

If the length of time series is even, then the number of harmonics will be half of the time series and except of 'a_q' and 'b_q' coefficients, others calculated by above equation. Nonetheless 'a_q' and 'b_q' coefficients is defined as: $a_q = \frac{1}{n} \sum \frac{n}{i=1} (-1) Z$. Then, the continuum can be created by following approximate procedure. By assuming that the sample ' r_1 ' is an unbiased estimation of *'P',* various choices of the harmonic number of 'k' between 'k = 0' and 'q' are assessed: $\lambda_k = \bar{S} \left[\frac{1 - r^2}{1 + r_1^2 - 2 r_1 Cos \frac{\pi k}{q}} \right]$. Where $\bar{S}$ is the average of all $q + 1$ 'raw' spectral estimate, $\hat{S}$ K, the computed spectrum. The resulting values of S_k can be plotted superposed on the sample spectrum and a smoothed curve passed through these values to reach the required null continuum.

RESULTS AND DISCUSSION

Man-Kendal calculations of monthly rainfall shows that discharge in months of January, February, march, June and august has continuously had a decreasing of heavy change (Table 1).

Table 1: Calculation of (t) Kendal statistic of average monthly rainfall / discharge

Station	Ghaleroudkhan (rainfall)	Ghaleroudkhan (discharge)
October	0.05	-0.6
November	0.02	-0.08
December	0.12	-0.02
January	-0.17	-0.35
February	-0.06	-0.32
march	-0.14	-0.37
April	0.04	-0.19
may	0. 12	-0.20
June	-0.21	-0.39
July	0.08	-0.13
august	-0.15	-0.32
September	0.06	-0.06

Table 2: Calculation of (t) Kendal statistic of average seasonal and annual of rainfall/discharge

Parameter	Autumn	Winter	Spring	Summer	Annual
Ghaleroudkhan rainfall	-0.05	0.01	-0.04	-0.2	0.05
Ghaleroudkhan discharge	-0.36	-0.19	-0.28	-0.43	0.13

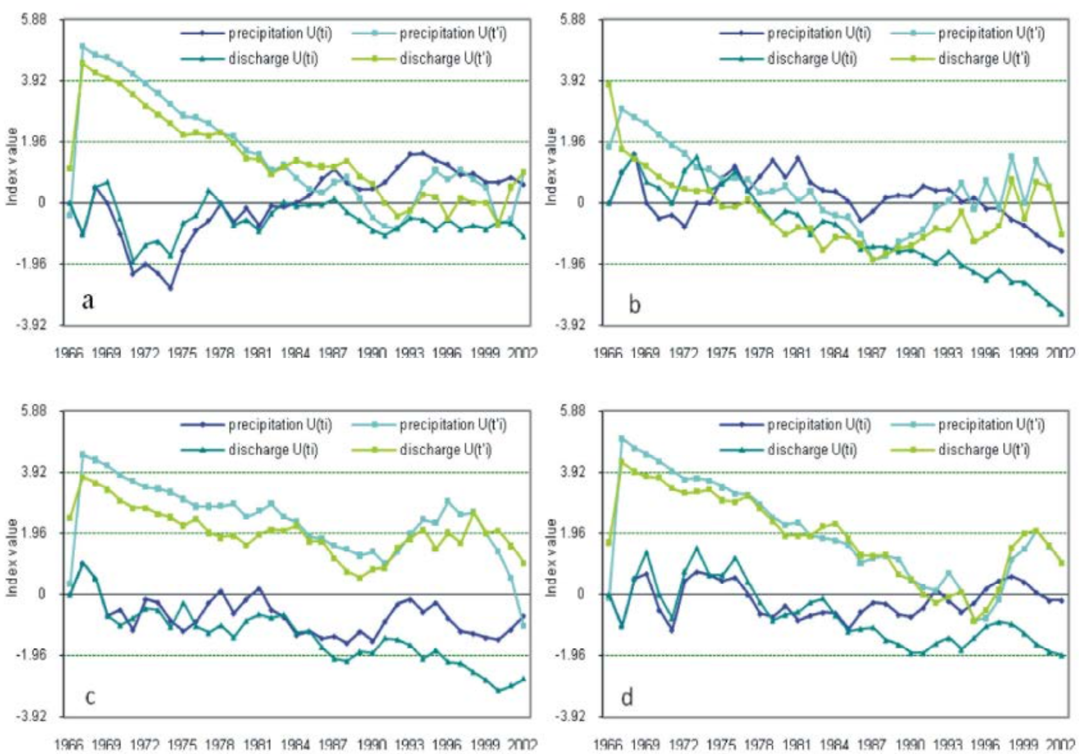

Fig. 2: Relationship between seasonal rainfall and discharge in Ghaleroudkhan basin

The diagrams of monthly components of u_i and u'_i showed that rainfall changes in all months. In general scale, a regular coincidence is seen between decreasing and increasing changes of rainfall and discharge. The intensity of the discharge change in relation to rainfall is originated from flood waters characteristic of basin under study. This issue is completely obvious in diagrams of months of January, February; march, June and August. Therefore, the discharge is dependent upon rainfall directly and any kind of small change in rainfall will lead to identical change in discharge (Figure 2).

Also, the Table '2' shows that in rainfall no kind of abrupt change has taken place in none of seasons, but amounts of '-0.36', '-0.28' and '-0.43' point to non random change in discharge in seasons of autumn, spring and summer (Table 2).

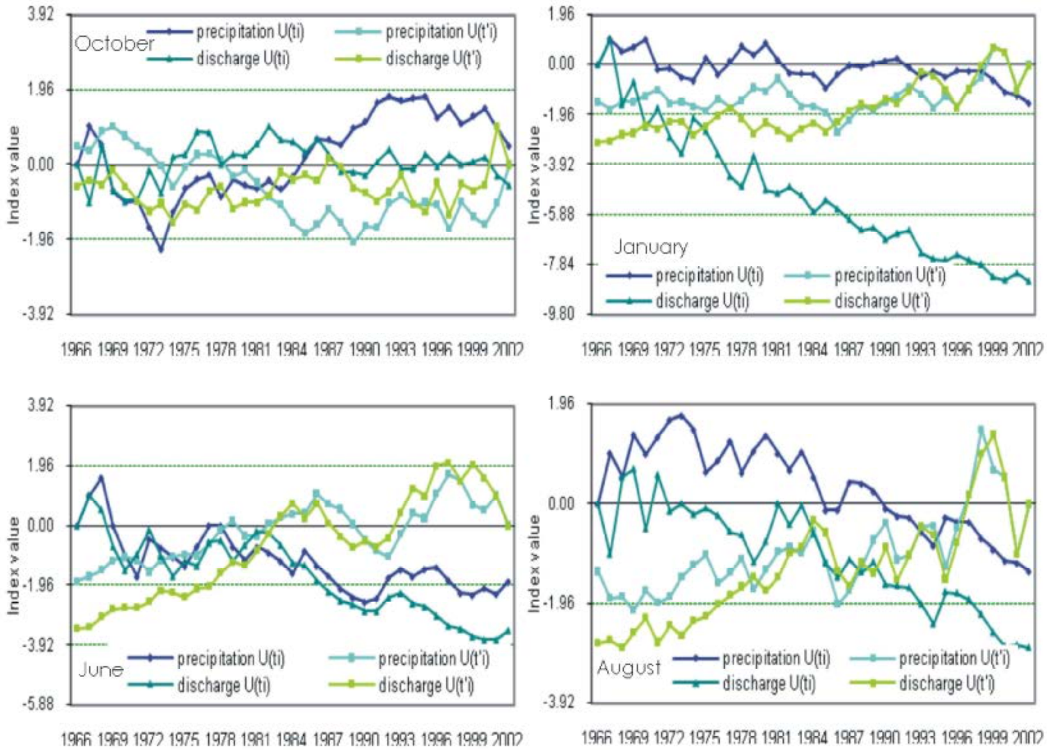

Fig. 3: Relationship between monthly rainfall and discharge in Ghaleroudkhan basin

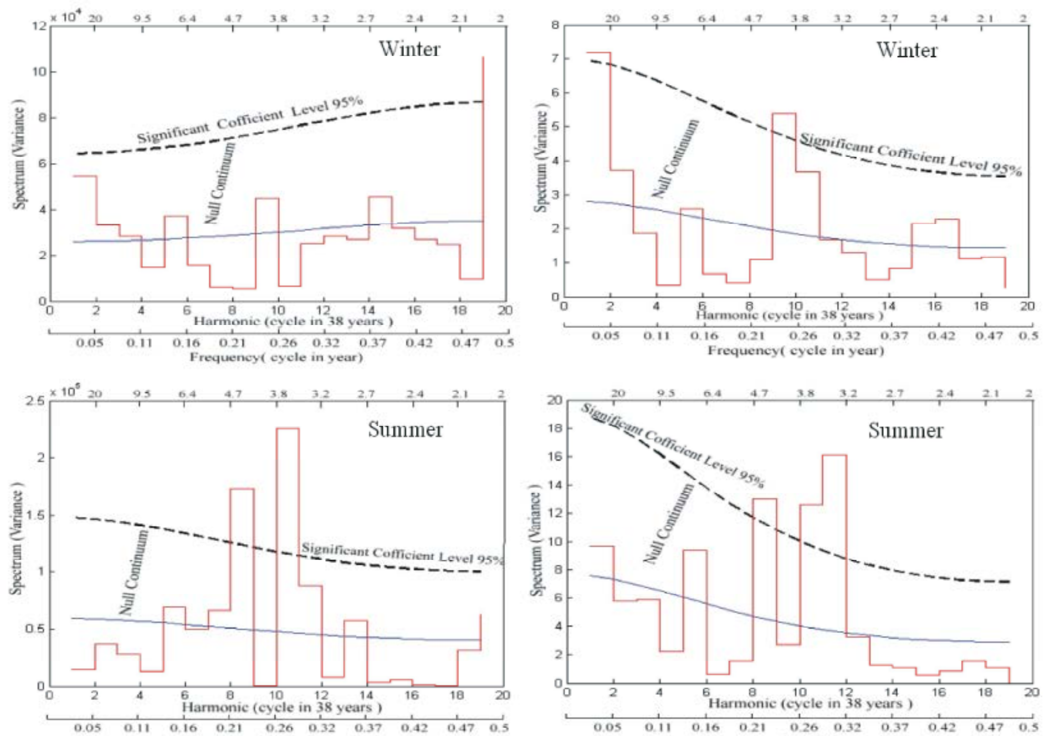

Fig. 4: Spectrogram of seasonal rainfall and discharge of Ghaleroudkhan basin

Table 3: Results of spectrum analysis for rainfall and discharge time series

	Significant Cycle (year)		Significant Frequency		Significant Harmonic	
Month	rainfall	Discharge	rainfall	discharge	rainfall	discharge
October	2.9	7.7-2.9	0.34	0.13-0.34	13	5-13
November	9.5-3.5	2.4	0.11-0.29	0.42	4-11	16
December	5.6-2.2	9.5-3.5-2.4	0.18-0.45	0.11-0.29-0.42	7-17	4-11-16
January	9.5-2.7	33.3	0.11-0.37	0.03	4-14	1
February	4.2-2	3.8-2.1	0.24-0.5	0.26-0.47	9-19	10-18
march	7.7-5.6-2.9	2.4	0.13-0.18-0.34	0.42	5-7-13	16
April	20	2	0.05	0.5	2	19
May	2	3.8	0.5	0.26	19	10
June	3.8	2.6	0.26	0.39	10	15
July	-	-	-	-	-	-
August	3.8-2	2	0.26-0.5	0.5	10-19	19
September	2	3.5	0.5	0.29	19	11
Autumn	7.7	7.7	0.13	0.13	5	5
Winter	2	33.3-4.2	0.5	0.03-0.24	19	1-9
Spring	12.8-3.5	33.3-2	0.08-0.29	0.03-0.5	3-11	1-19
summer	4.8-3.8	4.8-3.8-3.5	0.21-0.26	0.21-0.26-0.29	8-10	8-10-11

A noticeable trend is seen in autumn rainfall and discharge of figure 3 in the early period up to year '1964'. The analysis of statistic diagram of u_i and u'_i indicates that in years of '1974' and '1979' there are several abrupt changes in time series of rainfall. In addition, in winter, with regard to this fact that tails u_i of rainfall and discharge from the beginning up to end of period has good conformity with each other. The diagram shows an intersection of the u_i tails of two parameters in year '1989' which is representative of abrupt change and also in rainfall in year '2000' an abrupt change is observed with impact their tails. In spring, there are several points of abrupt changes in time series of discharge, but the tails of rainfall do not show any especial changes. In summer, the tails of u_i of rainfall and discharge at the beginning of period up to year '1983' shows high fluctuation. An intersection of tails of rainfall has occurred in year '1996' which is representative of probable change in mentioned parameter (Figure 3).

Also, the results suggested that there is the meaningful harmonics at significant level '95%' and calculated frequency and return period for any harmonic. Likewise, the trend is not observed in monthly and seasonal rainfall at significant level '95%', whereas it exists in January, spring and winter of discharge. In the rainfall and discharge of autumn the '-7.7' year cycle with '0.13' frequency was meaningful and observed the '4.8' and '3.8-' year cycles with '0.21' and '0.26' frequencies. But in winter and spring there is no any same cycle in the parameters. Non sinus cycles are not observed in monthly rainfall, whereas we aware of its existence in discharge of January (Table 3).

A graph proves to be '2.9-'year cycle with '0.34' frequency in January and '2.9-' year cycle with '0.34' frequency in august in two parameters. We now know that there are '9.5-7.7', '5.6-4.2', '2.7-3.8', '2-2.2', '20-' year cycles in monthly rainfall and '7.7-9.5', '2.9-3.8', '2-2.4-' year cycles in monthly discharge (Figure 4).

CONCLUSIONS

The effect of rainfall on discharge changes in Ghaleroudkhan is very obvious with regard to the same rhythm of u_i curves of both parameters. On the one hand, the total number of intersections of tails of u_i and u'_i of discharge has been more than rainfall in Ghaleroudkhan. Often at the beginning of period the tails of u_i of rainfall and discharge shows much coincidence in relation to the end of period. In autumn, the discharge has fewer trends in relation to other seasons, in other hand; the curves of u_i of parameters have more coincidence. Because rainfall rate in autumn has increased in Guilan and lead to increased rivers discharge, including Ghaleroudkhan. The increase of heat and melting of winter snows in mountainous regions to some extent is effective in increasing of discharge in Ghaleroudkhan, especially in spring. In winter and summer the reduction of rainfall has also often caused reduction of discharge during statistical period in Ghaleroudkhan basin as a whole. But rainfall trend is increasing in autumn and summer and also in winter and spring. The results of spectral analysis suggested that non sinus cycle of discharge is clear than seasonal rainfall and there is a trend in seasonal discharge. Also the harmonic cycle has not seen in winter and spring for both of parameters and it proves the lack of coincidence of between two parameters. The non sinus cycle has not seen in seasonal series for two parameters, except for the January of discharge. Thus, the obtained results from this research with Conway and Hulme's research (2005) on the sub-basins of Nile and Dixon *et al*. (2006) on analysis of streamflow in west *British* are the same as they believed that runoff changes in relation to rainfall is completely normal but its rate and intensity are different by considering the conditions of season, physiographic, climate and plant coverage of basins. Also [6] Kane and Teixeira (1990) asserted that there is '2-3' year cycle of rainfall in northeastern USA and [7] Madden and Jones (2001) identified '5.7' year cycles of rainfall in July month of Amarillo. Generally, the discharge has regular trend more than rainfall parameter during the period and analysis of point to point of parameters shows that changes of discharge is more than rainfall.

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REFERENCES

1. Brunetti, M., L. Buffoni and M. Maugeri, 2000. Precipitation Intensity Trends in Northern Italy. International Journal of Climatology, 20: 1017-1031. http://adsabs.harvard.edu/abs/2000IJCli..20.1017B
2. Buffoni, L., M. Maugeri and T. Nanni, 1999. Precipitation in Italy From 1833 to 1996. Theorical and Applied Climatology, 63: 33-40. http://adsabs.harvard.edu/abs/1999ThApC..63.33B
3. Camuffo, D., 1984. Analysis of the Series of Precipitation at Padova, Italy. Climatic Changes, 6: 57-77. http://cat.inist.fr/?aModele=afficheN and cpsidt=9608953.
4. Conway, D. and M. Hulme, 2005. Recent Fluctuations in Precipitation And Runoff over the Nile Sub-Basins and Their Impact on Main Nile Discharge. Journal of Climate Change, 25: 127-151. http://www.springerlink.com/content/g7286337u813nu28/
5. Domonkos, P., 2003. Recent Precipitation Trend in Hungary in Context of Larger Scale Climatic Changes. Natural Hazards Journal, 29: 255-271. http://www.springerlink.com/content/g246w23804n73220/
6. Kane, RP. and N.R. Teixeira, 1990. Power Spectrum Analysis of the Time-Series of Annual Mean Surface Air Temperatures. Climatic Change, 17: 121-130. http://www.springerlink.com/content/ump7w46555010327/
7. Madden, R. and R. Jones, 2001. A Quantitative Estimate of the Effect of Aliasing in Climatological Time Series. Journal Of Climate, 14: 3987-3993 http://journals.ametsoc.org/doi/pdf/10.1175/15200442%282001%29014%3C3987%3AAQEOTE%3E2.0.CO%3B2
8. Marengo, J., 1995. Variations and Change in South American Streamflow. Climatic Change Journal, 31: 99-117. http:// springerlink.com/index/U22U1328247740M1.pdf
9. Partal, T. and E. Kahya, 2005. Trend Analysis in Turkish Precipitation Data. Hydrological Processes Journal, 20: 2011-2026. http:// geofizika-journal.gfz.hr/.../geofizika_1617_19992000_53-63_pandzic.pdf.
10. Yue, S. and M. Hashino, 2003. Long Term Trends of Annual and Monthly Precipitation in Japan. Journal of the American Water Resources Association, 39: 587-596. http://cat.inist.fr/?aModele=afficheN and cpsidt=14957784