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Analysis of the Trend of the Number of Days with Snow and Slush of the Hydrometric Stations in Iran Using Non-Parametric Methods

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ABSTRACT

Today, recognizing the manner of the trend of the climate changes and especially the trend of the precipitation changes is very important. In this study, data on the number of days with snow and slush of 41 synoptic stations for a period of 40 years from 1965 to 2005 were extracted. A significant review was carried out by using three non-parametric methods of Mann-Kendall, Spearman and Autocorrelation. The results showed that all of the stations did not follow specific trends. Using the Mann-Kendall test, Shahr-e Kord, Isfahan and Zanjan stations in the confidence levels of 0.95 and 0.99 and Fasa, Torbat-e Heydarieh and Gorgan stations in the confidence level of 0.95 were significant that Shahr-e Kord, Zanjan and Torbat-e Heydarieh had increasing trend and Isfahan, Fasa and Gorgan had decreasing trend. In the Spearman test, 4 stations of Shahr-e Kord, Isfahan, Zanjan and Fasa were significant in the confidence levels of 0.95 and 0.99 and Torbat-e Heydarieh was also significant in the confidence level of 0.95 and Shahr-e Kord and Zanjan stations had decreasing trend (negative) and Fasa and Torbat-e Heydarieh stations had increasing trend (positive). In the Autocorrelation nonparametric test, the results indicated no significance in the confidence levels of 0.95 and 0.99 for the all of the stations except Shahr-e Kord and Zanjan stations in the confidence levels of 0.95 and 0.99 which had increasing trend and Bam in the confidence level of 0.95 which had decreasing trend.

Key words: Non-parametric Tests, Snow, Slush, Trend Analysis.

1. INTRODUCTION

Snow is one of the climate parameters which other factors also occur spontaneously with the snowfall. The proportion of the solid precipitation to the annual precipitation, retention and snow depth are among the most serious indicators of this adaptation to the ecological power and the residential structure of Iran. Thus, any change in this phenomenon at first, affect the available volume of water in the region and then caused drastic and unpredictable changes in the country's spatial structure from the economic, social and security aspects. In the generally arid and semi-arid lands of Iran, snowfall and snowy days are very valuable that the amount of snowfall, the number of snowy days, its proportion to rainy days, period of downfall and the beneficial and detrimental outcomes, each one can be the subject of separate research. While the average number of precipitation days in Iran is mentioned in the range from less than 10 to about 115 days, the annual maximum of snowy days is in North West region and it is about 25 days a year on average (Alijani, 2000). Aminінia and his colleagues (2010) have done a research about the analysis of the fluctuations of the heavy snow falls on the northwest of Iran that in order to analyze the changes of the heavy snowfall in North West area of country, he has used the daily statistics of the temperature and the snowfall of the 10 synoptic stations of the study area and concluded that the heavy snowfall in all stations and during the common statistics period faced a great fluctuation and had reduction trend. The initial look on a map of Iran which is prepared by overlaying of topographic, hydrographic, demographic and economic centers represents the appropriate overlap between the development centers with these layers, accordingly, the proportion of the solid precipitation to the annual precipitation, retention and snow depth are among the most serious indicators of this adaptation to the ecological power and the residential structure of Iran. In a study, the decreasing trend of the snowfall at North of Danube plain, in Bulgaria along with a significant increase in temperature of the winter months (December to February) for the period of 1931- 2005 have proved (Perkova, 2004). In another study, the trend analysis of precipitation time series of the past 50 years in Greece in relation to atmospheric circulation indices was studied. They applied least squares and Mann-Kendall methods on precipitation data of Greece and they believe that the annual and winter precipitation trend of Greece has been decreasing since 1984 (Feidas et al., 2007). Becker and his colleagues did the spatiotemporal analysis of precipitation trends in the Yangtze River. They calculated the precipitation trend of 36 stations located in that area over the past 50 years using Mann-Kendall method. The results showed that there is a significant positive trend in summer precipitation of most of the stations and also, they identified different spatial and temporal trends for different parts by the Yangtze interpolation with a spatial resolution of 0.5 geographical degree (Becker et al., 2006). Mann-Kendall is one of the most common and most used non-parametric methods of the time series trend analysis. This method is commonly and widely used in the analysis of the hydrological and meteorological series trend. Usually, the climate changes are slow and gradual and may not be noticeable in a short time of few years (Mohammadi, 2011). In a study, the existing of the increasing trend in the amount of water equal with snow of November, March and especially December and the existing of the significant decreasing trend in this index for January and February in New England were determined (Huntington ,2005). Most of the researches carried out in the field of snow in Iran are about the estimation of snow reserves volume and snow cover zonation and less research has been done about its temporal variation. The purpose of this research is to detect the possible changes in Iran's snowfall.

2. MATERIALS AND METHODS

2.1. The study area

Iran, with an area of 1648000 square kilometers is located in the northern hemisphere, in Asia and in the western part of the Iranian plateau. This country is located between meridian 44 ° and 64 ° East and two circuits of 25 ° and 40 ° North. About 90 percent of Iran located within Iranian plateau and the country is mountainous.

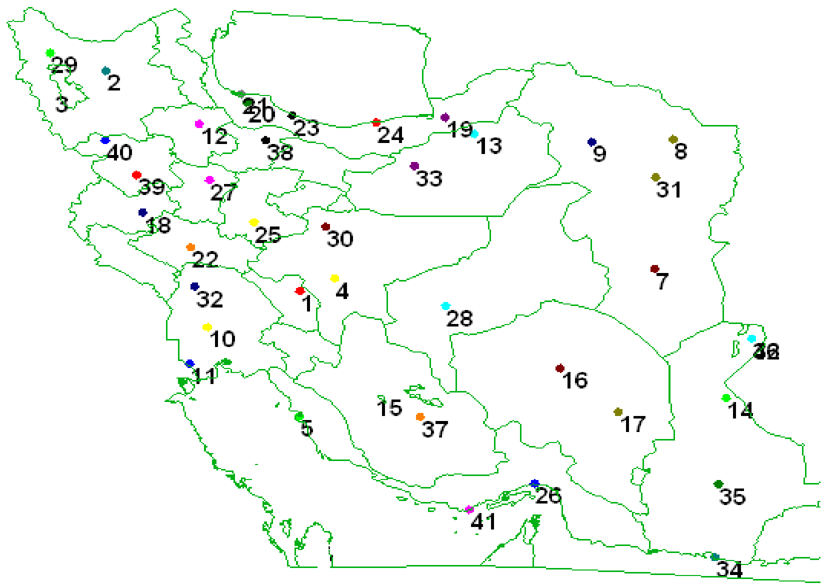

Figure 1 Location map of the synoptic stations

In this study, the maximum daily precipitation data from 41 synoptic stations (1) for a period of 40 years from 1965 to 2005 was received from the Meteorological Organization of country and data on the number of days with snow and slush were extracted using these data. After reviewing the statistical period duration the stations which had the highest statistics during the forty years of the study as well as suitable distribution in all latitudes and altitudes were selected to achieve acceptable results. The common statistical period for intended stations considered from the years 1965 to 2005 and then reconstruction of the statistical defects for stations that have the statistics defect in some years carried out by using reagents stations method. In order to check for trends in the statistical series, usually parametric and non-parametric methods are used. In this study, a significant review was carried out using three non-parametric methods of Mann-Kendall, Spearman and Autocorrelation in the confidence levels of 0.95 and 0.99.

2.2. Mann-Kendall Test

The statistical calculation steps of the test are as follows:

A: Calculation of the difference between each observation with each other and apply mark function and S parameter extraction which is obtained according to the following equation:

[1]

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_f = x_k)$$

Where n is the number of the observations and xk and xj by Kth and j are series data. The mark function is obtained according to the following equation:

[2]

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

B: Calculation of the variance is obtained from the following relationship:

[3]

$$\mathrm{var} = \frac{n(n-1)(2n+5) - \sum_{j=1}^{m} t_i(t_i-1)(2t_i-1)(2t_i+5)}{18} \qquad n > 10$$

$$\mathrm{var} = \frac{n(n-1)(2n+5)}{18} \qquad 0 \qquad 1 > \mathrm{n}$$

Where finally, n is the number of the observation data, *m* is reagent of the number of series that have at least one duplicate data and *t* is reagent of the data with equal value.

C: Finally, the z-statistic amount is determined by one of these relationships:

[4]

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{(\mathrm{var}(S)}} & 0 \quad < \mathrm{S} \\ 0 & 0 \quad = \mathrm{S} \\ \dfrac{S+1}{\sqrt{(\mathrm{var}(S)}} & 0 \quad > \mathrm{S} \end{cases}$$

2.3. Spearman Test

In statistics, Spearman's rank correlation coefficient which is indicated by the Greek letter ρ is a nonparametric statistics to measure the correlation coefficient between two random variables. The amount of these coefficients indicates the ability to express a variable as a monotonous function of the other variable. The Spearman correlation coefficient calculated as follows:

[5]

$$\rho = \frac{\sum i(x_i - \bar{x})(y_i - \bar{y})}{\sum i(x_i - \bar{x})^2 (y_i - \bar{y}) \sum i(y_i - \bar{y})^2}$$

2.4. Autocorrelation Test

Autocorrelation describe a correlation random process between values of the process at different times, as a function of the two times or of the time lag. If X be a repeatable process, and i be any point in time after the beginning of the process (i may be an integer for a discrete-time process or a real number for a continuous-time process.). Then X_i is the value produced by a given run of the process at time i. suppose that the process has mean μi and variance σi2 for each i. Then the definition of the autocorrelation between times s and t is:

[6]

$$R(s,t) = \frac{E\left[\left(X_t - \mu_t\right)\left(X_S - \mu_s\right)\right]}{\sigma_t \sigma_s}$$

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3. DISCUSSION & CONCLUSIONS

In this study, due to the importance of study and evaluating the snow occurrence trend in Iran, tried to examine the snow occurrence trend using the stations in each province. Generally, after collecting data on the number of days with snow and slush in time periods of 1965- 2005 as the statistical common base the available raw data from the archives of Meteorological Organization were extracted. In this study, in order to evaluate the trend, the non-parametric tests of Mann-Kendall, Spearman and Autocorrelation were used. Table 1 shows the comparison of the stations by three methods of Mann-Kendall, Spearman and Autocorrelation. Using the Mann-Kendall test, in the stations with long-term statistics there is a sudden change and in the evaluation of the trend of the number of days with snow and slush Shahr-e Kord Zanjan and Torbat-e Heydarieh had increasing trend and Isfahan, Fasa and Gorgan had decreasing trend although most of the stations were not significant during the study statistical period. In the Spearman test, Shahr-e Kord and Zanjan stations had decreasing trend (negative) and Fasa and Torbat-e Heydarieh stations had increasing trend (positive) and other stations were not significant in the confidence levels of 0.95 and 0.99; so, the trend evaluation did not carry out. After testing the Autocorrelation nonparametric test, to check the number of days with snow and slush of the selected stations, the results indicated no significance in the confidence levels of 0.95 and 0.99 for the all of the stations except Shahr-e Kord and Zanjan stations in the confidence levels of 0.95 and 0.99 which had increasing trend and Bam in the confidence level of 0.95 which had decreasing trend.

Table 1 The comparison of the stations by three methods of Mann-Kendall, Spearman and Autocorrelation

Autocorrelation			Spearman			Mann-Kendall			**station**
The significance level		z	The significance level		z	The significance level		z	
0.99	0.95		0.99	0.95		0.99	0.95		
significant	significant	2.72	significant	significant	3.12	significant	significant	2.9	**Shahr-e Kord**
not significant	not significant	0.67	not significant	not significant	0.41	not significant	not significant	0.37	**Tabriz**
not significant	not significant	-0.45	not significant	not significant	0.42	not significant	not significant	0.51	**Urmia**
not significant	not significant	0.62	not significant	not significant	1.52	not significant	not significant	1.49	**Khoy**
not significant	not significant	0.2	significant	significant	2.34	significant	significant	2.4	**Isfahan**
not significant	not significant	-0.54	not significant	not significant	1.02	not significant	not significant	1	**Kashan**
not significant	not significant	0.31	not significant	not significant	0.43	not significant	not significant	0.35	**Tehran**
not significant	not significant	1.51	not significant	not significant	1.16	not significant	not significant	1.05	**Birjand**
not significant	not significant	0.73	not significant	not significant	0.49	not significant	not significant	0.58	**Mashhad**
not significant	not significant	1.03	not significant	not significant	1.28	not significant	not significant	1.35	**Shahrud**
not significant	not significant	-0.72	not significant	not significant	0.13	not significant	not significant	0.16	**Zahedan**
not significant	not significant	0.01	not significant	not significant	0.61	not significant	not significant	0.59	**Shiraz**

Continue of **Table 1**: The comparison of the stations by three methods of Mann-Kendall, Spearman and Autocorrelation

Autocorrelation			Spearman			Mann-Kendall			station
The significance level		z	The significance level		z	The significance level		z	
0.99	0.95		0.99	0.95		0.99	0.95		
not significant	not significant	-2.04	not significant	not significant	1.44	not significant	not significant	1.4	**Gilan-Rasht**
not significant	not significant	-0.1	not significant	not significant	0.91	not significant	not significant	1.1	**Bandar-e Anzali**
not significant	not significant	-0.02	not significant	not significant	0.04	not significant	not significant	0.02	**Khorramabad**
not significant	not significant	-0.5	not significant	not significant	1.32	not significant	not significant	1.29	**Ramsar**
not significant	not significant	-0.21	not significant	not significant	1.6	not significant	not significant	1.62	**Babolsar**
not significant	not significant	0.008	not significant	not significant	0.72	not significant	not significant	0.7	**Arak**
not significant	not significant	0.68	not significant	not significant	0.47	not significant	not significant	0.23	**Hamadan-Noje**
not significant	not significant	1.28	not significant	not significant	0.01	not significant	not significant	0.02	**Yazd**
not significant	not significant	0.22	not significant	not significant	0.33	not significant	not significant	0.22	**Zabol**
not significant	not significant	1.13	significant	significant	2.67	not significant	significant	2.28	**Fasa**
not significant	not significant	0.08	not significant	not significant	0.05	not significant	not significant	0.12	**Qazvin**
not significant	not significant	0.7	not significant	not significant	1.05	not significant	not significant	0.94	**Sanandaj**
not significant	not significant	0.21	not significant	not significant	1.42	not significant	not significant	1.49	**Saqqez**
not significant	not significant	0.69	not significant	not significant	0.021	not significant	not significant	0.12	**Kerman**
not significant	significant	1.76	not significant	not significant	0.73	not significant	not significant	0.66	**Bam**
not significant	not significant	0.87	not significant	not significant	1.35	not significant	not significant	1.15	**Kermanshah**
not significant	not significant	0.29	not significant	not significant	1.62	not significant	significant	1.68	**Gorgan**
not significant	not significant	-0.81	not significant	not significant	0.36	not significant	not significant	0.48	**Sabzevar**
not significant	not significant	0.73	not significant	significant	1.81	not significant	significant	1.75	**Torbat-e Heydarieh**
significant	significant	2.39	significant	significant	2.86	significant	significant	2.64	**Zanjan**
not significant	not significant	-0.73	not significant	not significant	0.23	not significant	not significant	0.18	**Semnan**

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4. RESULTS

Based on the study statistical methods and then its occurrence trend based on the graphic Mann-Kendall test were evaluated. The results of the data analysis showed that the trend of the number of days with snow and slush in all the study stations and in the statistical period mostly were not significant and only Shahr-e Kord, Isfahan and Zanjan stations in the confidence levels of 0.95 and 0.99 and Fasa, Torbat-e Heydarieh and Gorgan stations in the confidence level of 0.95 were significant that Shahr-e Kord, Zanjan and Torbat-e Heydarieh had increasing trend and Isfahan, Fasa and Gorgan had decreasing trend. In the Spearman test, only 4 stations of Shahr-e Kord, Isfahan, Zanjan and Fasa were significant in the confidence levels of 0.95 and 0.99 and Torbat-e Heydarieh was also significant in the confidence level of 0.95 which Shahr-e Kord and Zanjan stations had decreasing trend (negative) and Fasa and Torbat-e Heydarieh stations had increasing trend (positive). After testing the Autocorrelation nonparametric test, to check the number of days with snow and slush of the selected stations, the results indicated no significance in the confidence levels of 0.95 and 0.99 for the all of the stations except Shahr-e Kord and Zanjan stations in the confidence levels of 0.95 and 0.99 which had increasing trend and Bam in the confidence level of 0.95 which had decreasing trend. Since the climate change is a very complex phenomenon and requires comprehensive studies, it is recommended for more accurate planning and decisions, other statistical methods and different models of evaluating the climate change on all climatic elements and at the regional scale be examined.

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