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ORIGINAL PAPER

Spatio-temporal trend analysis of solid precipitation in Northwest Iran

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Abstract

Most studies and climate models use 24-h time scales, while the atmospheric characteristics that determine the type of precipitation can change in less than 24 h. Accepting the average rainfall or 24-h temperature means accepting the stagnant atmospheric conditions in 24 h; however, it is not the case in reality. Therefore, the present study deals with the spatial-temporal trend and real slope of solid precipitation on hourly, daily, and annual scales in 19 stations in Northwestern Iran (1951–2018). In the first step, the solid precipitation codes were extracted from 3-h records from studied metrological stations, and then the variations of trend and the slope of solid precipitation line were calculated through Mann–Kendall (MK) test and the Sen's slope estimator. Some remarkable results indicated that 1) the solid precipitation trend in all three scales is declining; 2) the annual solid precipitation trend in all stations except Khoy and Parsabad is negative; 3) on an hourly scale, UTC 0.3.00 in Kaleybar and UTC 15:00 in other stations have the highest hourly declining trends; 4) in daily scale, data has almost declining trend and the difference in solid precipitation during night and day (except three stations) is negligible; 5) Tabriz, Ardabil, Urmia, Khoy, and Kaleybar are the stations with a significant difference in SYNOP solid precipitation rate, while in other 14 stations, this difference was not observed; 6) the correlation of height and the annual solid precipitation trend is about −0.46; and finally, 7) in the whole region, the annual solid precipitation trend values have the highest correlation with UTC 15:00.

Keywords Solid precipitation · Eight SYNOP · Mann–Kendall (MK) test · Northwest Iran

Introduction

One of the significant characteristics of climate change is the variability of precipitation patterns, which affects the water resources of a region (Udayashankara et al. 2016; Nury et al. 2016). In the moderate and high altitudes, where precipitation is mostly solid, what reaches the earth's surface depends on the weather conditions where the snowflakes fall (Ye et al. 2013). It can be said that the potential advantages and disadvantages of increasing precipitation under global warming conditions in high-latitude regions depend on precipitation rate and type (Ye 2008). Therefore, one of the main issues in modern hydrology is to determine the effects of climate change on solid and liquid precipitation, their trend, and statistical distribution (Avanzi et al. 2014). In mountainous areas, solid precipitation (snow), in particular, plays a key role in the cold season (Li et al. 2020). In addition to the climate and hydrological effects of precipitation, it directly and indirectly affects the environmental planning and life of human communities. This dependency of human communities on precipitation could be viewed both from positive and negative aspects. For example, despite the positive effects of solid precipitation (especially snow) in the mountainous areas on the water resources, it can impose various problems on the transportation

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system and cause human and financial damages. Therefore, the investigation of precipitation is one of the topics that has attracted the attention of climatologists and hydrologists. Most hydrological studies utilize 24-h precipitations trend, while the atmospheric features determining the precipitation phase vary in a time interval less than 24 h; i.e., the solid and liquid precipitation frequencies might vary in different hours of the day for some reasons such as diurnal changes in temperature and warm and cold fronts passage (Feiccabrino 2020). Accepting the average rainfall and 24-h temperature means accepting the stagnant atmospheric conditions within the day; however, it is not the case in reality. Therefore, the present study has been carried out to investigate the solid precipitation variation trend at various hours of the day as well as on an annual scale for some areas in Northwestern Iran. This region with an approximate area of 100,000 km^2 and the difference of over 4000 m in altitude is considered a mountainous area and includes East Azarbaijan, West Azarbaijan, and Ardabil provinces (Fig. 1 and Table 1). The average annual precipitation of this area is about 352 mm, and on average, 5500 cases of 3-h solid precipitation are recorded for each station (1951–2018).

The studied area has been subject to climate changes the same as most areas of the world, or its causative agents increased (RezaiBanafsheh et al. 2015; Jahanbakhsh Asl et al. 2016; Rasouli et al. 2019; GhaffariGilandeh et al. 2020), and most of its meteorological elements experienced significant changes, especially precipitation and temperature elements (Faramarzi Fard and Ghasemi 2013). It seems that the spatial-temporal conversion of solid precipitation to liquid is becoming more and more noticeable and results of studies in the world and Iran confirm this claim. Feiccabrino (2020) used the thresholds of three variables of air temperature (AT), Dew point temperature (DP), and wet bulb (WB) in time intervals of 1, 3, 6, 12, and 24 h to analyze the uncertainty of model in determination of precipitation phase. The results indicate that the implementation of the model with data in 1–24-h time interval changes the uncertainty of the model up to 35 to 65% such that change in time scale from 24 to 1 h decreases the error in the classification of precipitation type about 29.3% in AT threshold, 26.7% in DP, and 39.9% in WB. That is, the shorter the time scale, the higher will be the precision of models in distinguishing the precipitation phase. Finally, it was proposed that using WB or reducing the time scale to 1 or 3 h to study the precipitation phase in cold regions could provide more reliable results. Serquet et al. (2011) studied the variations ratio of snowy days to rainy days in Switzerland and realized a decrease in snowy days at low altitudes and in spring. Nikolova et al. (2013) studied the variations in snowy and rainy days and its relationship with temperature in Slovakia. The results showed that the average monthly temperature leads to changes in the snowy and rainy days.

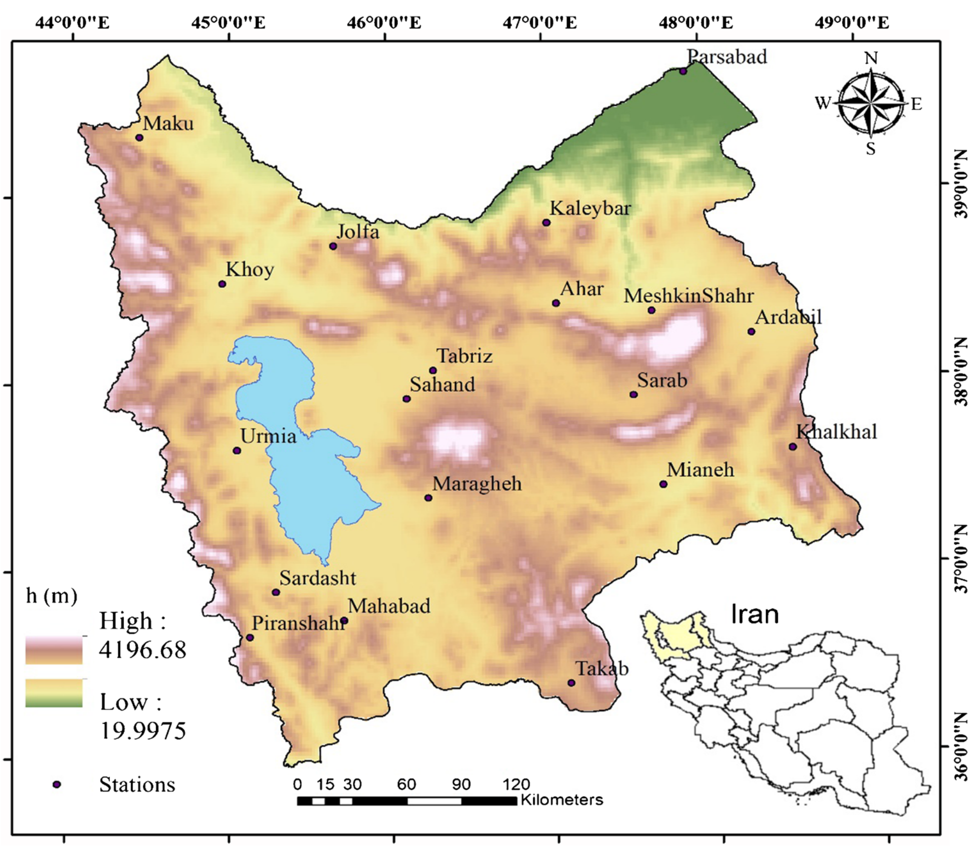

Fig. 1 The digital map of the height and location of the studied stations

Table 1 The specifications of studied stations (the end of the statistical period of all stations is 2018)

	Station	Height (m)	Longitude	Latitude	Start date	Rainfall average (mm)	Temperature average (°C)
1	Ardabil	1332	48°17′	38°15′	1/1/1984	295.5	9.2
2	Urmia	1328	45°3′	37°40′	1/1/1951	338.9	11.6
3	ahar	1390.5	47°4′	38°26′	1/1/1986	285.2	11
4	Parsabad	31.9	47°55′	39°39′	1/1/1992	271.2	15.2
5	Piranshahr	1455	45°8′	36°40′	1/1/1994	672.7	12
6	Tabriz	1361	46°17′	38°5′	1/1/1951	285	12.6
7	Takab	1817.2	47°6′	36°24′	1/1/1992	338.6	9.4
8	Jolfa	736.2	45°40′	38°45′	1/1/1986	206.2	15
9	Khalkhal	1796	48°31′	37°38′	1/1/1992	378.6	8.2
10	Khoy	1103	44°58′	38°33′	1/1/1960	289.2	12.1
11	Sarab	1682	47°32′	37°56′	1/1/1989	241.5	8.7
12	Sardasht	1556.8	45°29′	36°9′	1/1/1998	841.2	13.1
13	Sahand	1641	46°7′	37°56′	1/1/1996	202.7	12.3
14	Kaleybar	1180	47°1′	38°52′	1/1/2000	386.8	12.4
15	Maku	1411.3	44°26′	39°20′	1/1/1987	302.8	10.6
16	Maragheh	1477.7	46°16′	37°24′	1/1/1984	309.9	13.2
17	Meshkinshahr	1568.5	47°40′	38°23′	1/1/1996	373	10.8
18	Mahabad	1351.8	45°4′	36°45′	1/1/1989	403.8	13
19	Mianeh	1110	47°42′	37°27′	1/1/2000	278	14

Faramarzi Fard and Ghasemi (2013) studied the frequency of snow days for 50 synoptic stations in Iran during the years 1970 to 2000. The results showed that the trend of snow days has decreased after 1993. Avanzi et al. (2014) studied the statistical distribution of volume and time of solid, liquid, and mixed precipitation in Italy through Spearman, Mann–Kendall (MK), and Kolmogorov–Smirnov test. The results indicated that the time of occurrence of different types of precipitation varies with altitude. Bahrami et al. (2015) studied the annual variation of solid-to-liquid precipitation rate in Mehrabad, Abali, Tabriz, and Ardabil stations. The results showed that the variation trend has been extremely declining in Mehrabad and Abali stations and almost constant in Tabriz station and has a mild ascending slope in Ardabil. Decreasing or increasing changes in these stations have probably occurred due to different effects of climate and temperature change on them (Soltani et al. 2016). Basati et al. (2015) studied the variation of precipitation types and clarified how the relative humidity and temperature affect them in the Kermanshah station (1981–2010). The results of Mann–Kendall (MK) and regression tests showed that the number of precipitation days has a declining trend. Heydari (2016) studied the changes in the type and amount of precipitation during the cold season (1951–2012) in 7 synoptic stations in Northwestern Iran. The results showed that in most stations, the downward trend of snowfall has started since 1994. McCabe et al. (2018) studied the long-term trend of winter snowfall changes in the west of America in 1951–2014. The results showed a negative long-term trend of snowfall for most units. Moreover, other studies have been carried out in Iran and around the world by Pons et al. (2010), Ye (2008), and Raziei et al. (2018). The previous studies on variations of solid precipitation in different regions of the world indicated a declining trend in solid precipitation in most areas.

Methods and materials

In this study, solid precipitation codes (22, 24, 26, 56, 57, 66, 67, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 85, 86, 93, 94) in the SYNOP main (SM) and SYNOP intermediate (SI) have been used including eight SYNOP of 00, 03, 06, 09, 12, 15, 18, and 21 UTC. First, data related to solid precipitation of synoptic and metrological stations of the studied area in 1951–2018 were taken from the Meteorological Organization. As far as the period of data record and data homogeneity is very significant for climate studies, the stations with the short statistical period and heterogeneous data were excluded, and in the end, 19 stations were selected for the present study (Table 1). Then, the frequency and hourly and annual solid precipitation trends in the cold months of the year were obtained, and the results were presented in the form of a table and interpolated maps.

Mann–Kendall test

This test was first presented by Mann in 1945 and then extended by Kendall in 1975. One of the advantages of this method is that it is suitable to be used in time series that do not follow certain statistical distribution (Sari Sarraf et al. 2016; Qaisrani et al. 2021). In fact, the independence of the MK test from normal data distribution and low sensitivity to outliers is one of the features of this test (Panda and Sahu 2019). This simple and strong test is used to determine the precipitation trend in environmental data, as recommended by the World Meteorological Organization (WMO) (Kocsis et al. 2020). The present study has used MK to investigate the solid precipitation trend in various hours of the day and year. In this test, according to H_0, data are taken from independent series with a uniform distribution that is in the form of the following equations (Bagherpour, Seyyedian et al. 2017).

$$s = \sum_{i-1}^{N-1} \sum_{j-i+1}^{N} sgn\left(x_j - x_i\right), \text{ where } sgn(x) = \begin{cases} +1, x > 0 \\ 0, x = 0 \\ -1, x < 0 \end{cases} \quad (1)$$

where the variance of the process is determined by Eq. (2):

$$Q_s^2 = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{i-1}^{m} t_i(t_i - I)(2t+5)\right] \quad (2)$$

In which m is the number of categories or node data and t_i is the number of node data in each m category.

$$z = \begin{cases} \frac{s-1}{Q_s} if\ s > 0 \\ 0 if\ s = 0 \\ \frac{s+1}{Q_s} if\ s < 0 \end{cases} \quad (3)$$

The z value obtained from the above equations will be compared with those obtained from the normal distribution table with the intended reliability level. If the calculated z value is bigger than the z value in the table, the zero hypothesis on lack of trend or intended reliability level will be rejected. In the case of the presence of a trend, positive z values indicate the positive trend and negative z values indicate the negative trend.

Sen's slope estimator method

Sen's nonparametric estimator method is used for the prediction of the real slope of hydrometrical time series data (Hussain et al. 2015). The same as the MK method, this method is based on the concept of the difference between the observations of a time series; however, MK just shows the trend while Sen indicates the trend slope value. Therefore, in order to calculate the real slope of the trend of solid precipitation in Northwestern Iran, Sen's slope method was used. In this method, the slope between each data pair in series is calculated the median of the slopes' series will be extracted (Sen 1968).

$$\beta = Median\left(\frac{x_j - x_i}{j-1}\right) \forall | < j \quad (4)$$

In this equation, β is the slope estimator of the trend line, and x_i is the ith observed value. Positive (negative) β values indicate the increasing (decreasing) trend in the data series (Mirabbasi and Dinpashoh 2013).

Findings and discussion

In Fig. 2, it can be seen that the annual solid precipitation trend is descending in all stations. Except for Khoy, Piranshahr, Sardasht, Parsabad, Jolfa, and Ardabil which have a negligible declining trend, the other 13 stations show a significant negative trend. On an annual scale, Mahabad station with a mean solid precipitation rate has the most descending graph.

A summary of the results related to the calculation of trend and slope of solid precipitation in the selected stations of Northwestern Iran calculated through MK test (Z) and Sen's slope (Q) is presented in Table 2. In this table, the SUM column shows the trend values of total solid precipitation for each station. The negative values represent the declining trend of solid precipitation, and on the contrary, positive values represent the increasing trend of solid precipitation. The results obtained from Table 2 indicate that the trend of solid precipitation in the hourly and annual scales is mostly negative and the average trend of the region on an annual scale is −1.04. The highest annual negative trend is observed in the Maragheh station (KM statistics of −5 and Sen's slope value of −1.27) and Mahabad station (KM statistics of −4 and Sen's slope value of −2), and the lowest is observed in Jolfa station. Overall, except for Khoy and Parsabad stations, the other stations show a negative trend. This trend is not meaningful despite the fact that these two stations show a positive trend in solid precipitation.

On an hourly scale, Kaleybar, Meshkinshahr, Maragheh, Maragheh, Mianeh, Maragheh, Mahabad, and Meshkinshahr stations have the highest negative trend, respectively, at 3:00, 21:00, 12:00, 9:00, 15:00, 6:00, 00.00, and 18:00 UTC and Khoy stations show the highest positive trend at 15:00, 18:00, and 21:00 and Parsabad at all hours except SYNOP 00:00. Overall, the mean solid precipitation trend in the hourly scale for the whole area is −0.6, and on average, the highest negative trend in the area is related to 15:00 UTC. Concerning Table 2, the hourly variations of trend and real slope of solid precipitation of some stations are considerable; e.g., Kaleybar station shows relatively high negative values at 3:00, 6:00,

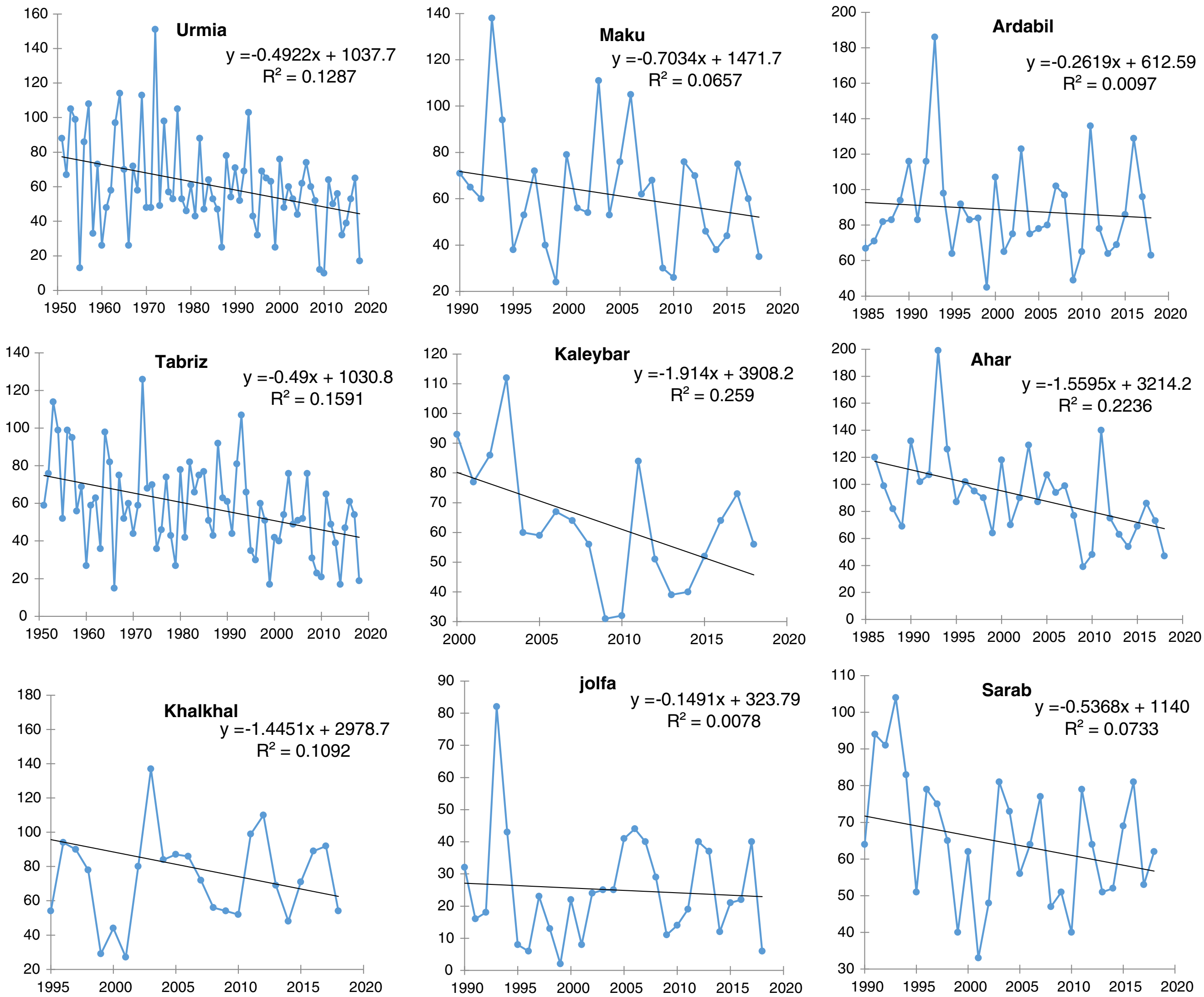

Fig. 2 The solid precipitation trend in stations (vertical axis is the mean frequency of solid precipitation per year)

and 15:00; however, the values are increasing at 18:00, 21:00, and 00:00. Despite hourly variations, the trend of solid precipitation does not significantly change in most stations on a daily scale. In addition, the variance analysis of the daily data showed that all stations except Ardabil, Piranshahr, and Kaleybar are not significantly different in terms of solid precipitation frequency within the day.

The correlation between the altitude of the stations and the annual and hourly solid precipitation trend of stations were calculated by considering the results of some studies on the precipitation correlation and altitude, in one hand, and some variables such as the altitude variations of the area and the installation of stations in various heights and their differing precipitation statistics (Fig. 5). The results of these calculations showed that on an annual scale, the correlation of the mentioned factors in the area is about −0.46, which is reliable at an error level of 5%. Moreover, the correlation between the hourly trend of solid precipitation and altitude showed that the trend of SYNOP 15:00 and 00.06 has the highest negative meaningful correlation with altitude. The presence of negative and positive correlations between various SYNOP is another result that observed, such that in some hours such as 21:00 and 18:00 UTC, there is a highly significant meaningful correlation at the reliability of 99%.

After calculation of the solid precipitation trend of Northwestern Iran through the MK test, the results have been presented in 5 categories for hourly and annual scales as interpolated maps. Figure 3 shows each of the outputs obtained

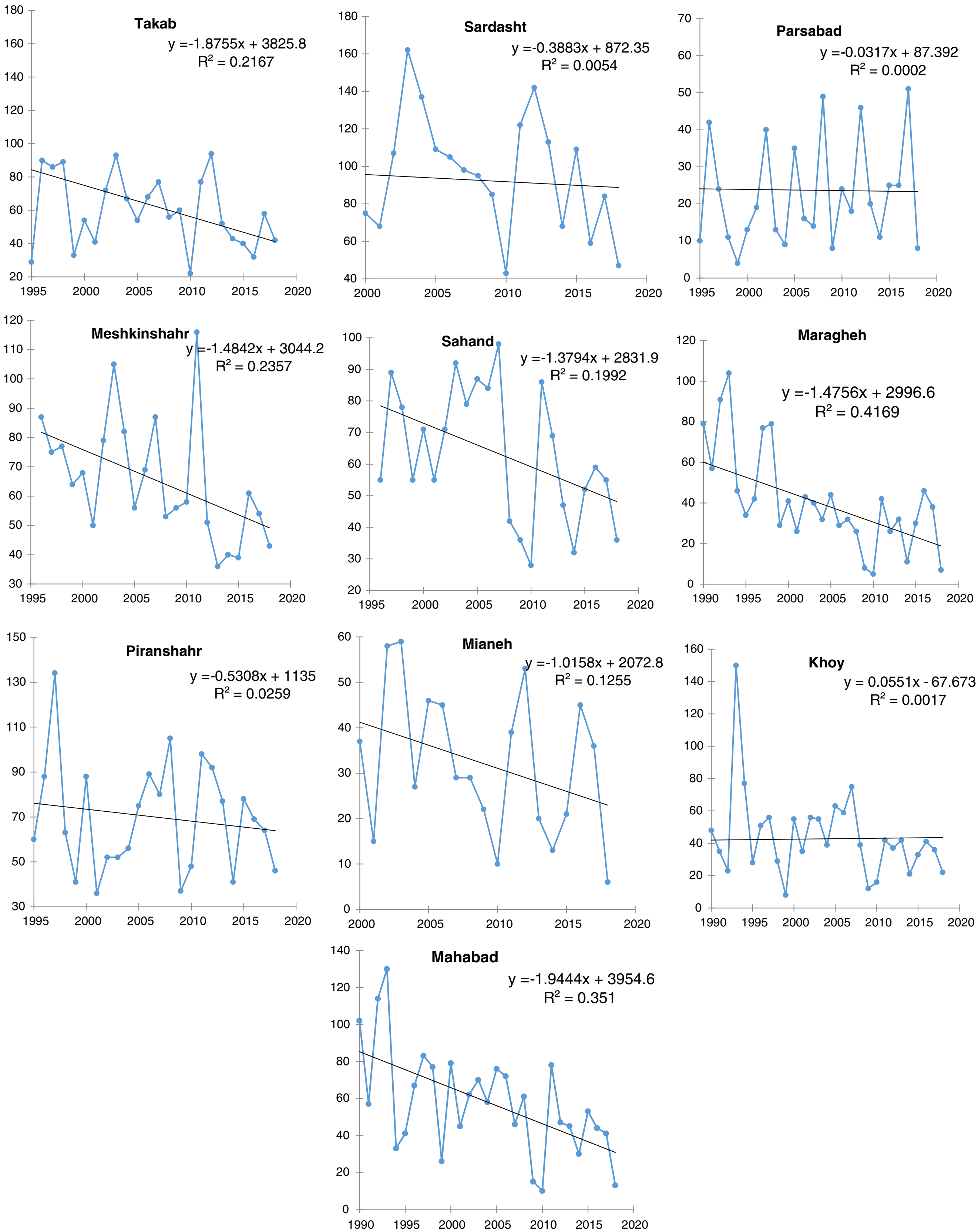

Fig. 2 (continued)

Table 2 The results of solid precipitation trend through MK (Z) and Sen's slope (Q) in eight SYNOP and annual sum (SUM)

Station		SUM	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00	Day	Night
ahar	**Z**	−3.7[a]	−2.91[a]	−3.49[a]	−3.89[a]	−2.05	−3.94[a]	−3.11[a]	−3.06[a]	−3.58[a]	−3.75[a]	−3.76[a]
	Q	−1.5	−0.2	−0.222	−0.212	−0.129	−0.146	−0.17	−0.19	−0.282	−0.63	−0.88
Ardabil	**Z**	−0.7	−0.56	−1.74	−0.87	−0.12	−0.35	−0.11	−1.28	−0.97	−0.17	−0.09
	Q	−0.2	0	−0.074	−0.045	0	0	0	−0.063	−0.043	0	−0.18
Jolfa	**Z**	−0.2	−0.14	−0.56	−0.1	−1.26	−0.28	0.43	0.53	−0.39	−0.25	−0.25
	Q	−0.04	0	0	0	0	0	0	0	0	−0.02	0
Kaleybar	**Z**	−3.35[a]	***1.6***	**−5.23**[a]	−3.77[a]	−2.04	−3.23	−3.65[a]	0.27	1.46	−3.59[a]	−0.18
	Q	−1.87	0	−0.529	−0.444	−0.25	−0.333	−0.429	0	0	−1.4	0
Khalkhal	**Z**	−1.8	−1.46	−1.41	−3.65[a]	−2.75	−1.73	−1.85	−0.59	−1.03	−2.37	−1.43
	Q	−1.33	−0.15	−0.1	−0.364	−0.15	−0.188	−0.118	−0.05	−0.063	−0.76	−0.52
Khoy	**Z**	0.4	−1.58	−1.68	−2.47[a]	−1.98[a]	−0.41	***3.65***[a]	3.21[a]	2.86[a]	−0.17	0.47
	Q	0.07	−0.038	−0.061	−0.059	−0.04	0	0.08	0.067	0.049	0	0.04
Mahabad	**Z**	−4[a]	**−4.16**[a]	−2.51	−4.17[a]	−4.25[a]	−3.54[a]	−4.15[a]	−3[a]	−3.53[a]	−4.05[a]	−3.66[a]
	Q	−2	−0.267	−0.143	−0.333	−0.296	−0.222	−0.24	−0.176	−0.211	−1.06	−0.88
Maku	**Z**	−1.6	0.13	−1.33	−2.84[a]	−1.72	−0.79	−0.84	−1.87	−2.42	−1.6	−1.38
	Q	−0.76	0	−0.074	−0.185	−0.103	−0.048	−0.042	−0.083	−0.093	−0.4	−0.25
Maragheh	**Z**	**−5**[a]	−2.44[a]	−4.15[a]	−5.6[a]	**−4.87**[a]	**−5**[a]	**−4.38**[a]	−2.69[a]	−3.44[a]	−5.54[a]	−3.45[a]
	Q	−1.27	−0.125	−0.143	−0.238	−0.167	−0.25	−0.185	−0.1	−0.158	−0.8	−0.53
Meshkinshahr	**Z**	−3.8[a]	−2.74	−2.07	−1.73	−0.04	−0.46	−1.44	**−3.85**[a]	**−5.16**[a]	−1.56	−5.42[a]
	Q	−1.6	−0.238	−0.15	−0.182	0	0	−0.091	−0.375	−0.429	−0.33	−1.27
Mianeh	**Z**	−2.7	−2	−2.24	**−4.4**[a]	−3.28	−2.14	−0.8	0.31	−1.51	−3.14	−1.92
	Q	−1.14	−0.111	−0.143	−0.357	−0.222	−0.111	0	0	−0.059	−0.64	−0.46
Urmia	**Z**	−2.24[a]	−0.86	−1.72[a]	−1.34	−3.16[a]	−2.66[a]	−2.77[a]	−1.63	−1.33	−2.42[a]	−1.76[a]
	Q	−0.44	0	−0.045	−0.051	−0.105	−0.072	−0.067	−0.042	−0.03	−0.3	−0.15
Parsabad	**Z**	***0.5***	−0.9	0.37	0.06	0.25	0.46	1.29	1.69	0.52	0.43	0.29
	Q	0.13	0	0	0	0	0	0	0	0	0.06	0
Piranshahr	**Z**	−0.6	*0.59*	−2.91	−5.18[a]	−2.84	−2.35	−0.81	1.79	2.51	−3.04[a]	1.05
	Q	−0.5	0	−0.212	−0.333	−0.179	−0.1	0	0.16	0.268	−0.72	0.25
Sahand	**Z**	−2.7	−1.6	−1.34	−2.76	−2.81	−2.98	−4.14[a]	−2.2	−2.35	−3.72[a]	−1.63
	Q	−1.42	−0.091	−0.118	−0.25	−0.133	−0.222	−0.286	−0.125	−0.154	−0.88	−0.42
Sarab	**Z**	−1.5	−0.38	−3.48[a]	−3[a]	−0.95	−0.5	−3.03[a]	0.7	0.51	−2.45	−0.75
	Q	−0.53	0	−0.174	−0.167	0	0	−0.16	0	0	−0.41	−0.14
Tabriz	**Z**	−2.6[a]	−2.74[a]	−2.32[a]	−1.76[a]	−2.32[a]	−2.14[a]	−0.93	−2.5[a]	−2.38[a]	−2.23[a]	−2.75[a]
	Q	−0.5	−0.077	−0.056	−0.059	−0.075	−0.059	0	−0.059	0.053	−0.22	−.26
Takab	**Z**	−2.7[a]	−1.65	−3.65	−4.05[a]	−3.99[a]	−4.22[a]	−3.36[a]	−0.15	−0.26	−4.78[a]	−1.77
	Q	−1.9	−0.133	−0.263	−0.375	−0.25	−0.294	−0.25	0	0	−1.22	−0.6
Sardasht	**Z**	−0.6	0.39	−0.35	−2.8	−2.37	−1.42	−0.83	***1.24***	0.77	−1.77	0.62
	Q	−0.71	0	0	−0.258	−0.243	−0.216	−0.108	0.106	0.139	−0.75	0.24

[a] Trend meaningfulness

from the solid precipitation trend variation of the stations in eight SYNOP, where the light color areas indicate a higher negative trend, and as approaching the bold areas, the negative trend decreases, and even in some hours, a negligible positive trend is also observed. For example, in Fig. 3a, which is the interpolated map of the solid precipitation trend of stations at an annual scale, the negative trend is considerable in central areas of the studied site. This negative trend decreases at east, northwest, and southwest, and it reaches its minimum value at Khoy and Parsabad stations. Overall, it can be said that

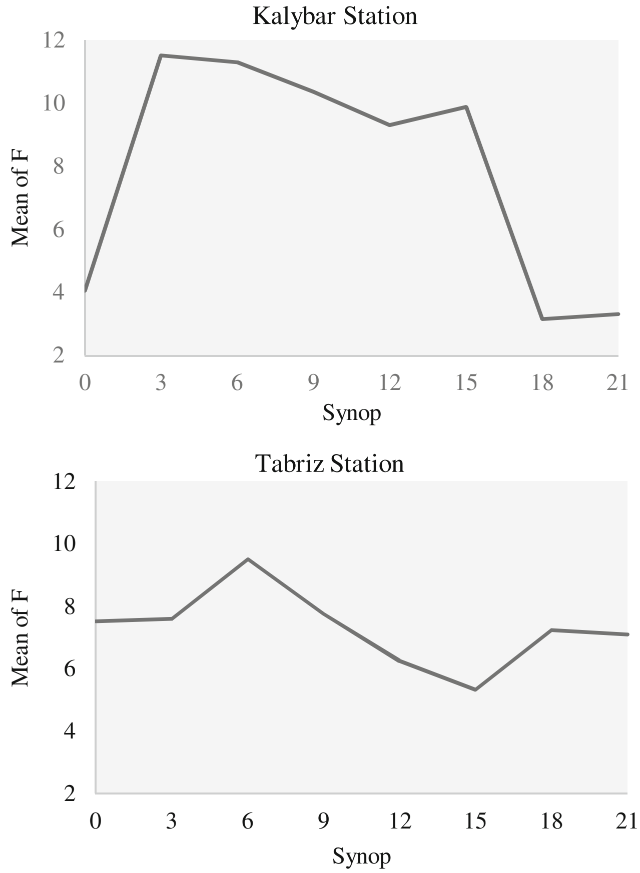

Fig. 3 The outputs of interpolation of MK test values of stations at eight SYNOP and annual sum (SUM)

concerning the outputs, the central areas usually have more declining trends than other areas; however, in each SYNOP, the trend values are different.

The investigations show some differences in solid precipitation trend values. However, as previously mentioned, there are some differences in the frequency of solid precipitation between different hours in each station. Therefore, variance analysis was used to analyze the difference between the SYNOP of each station. To this end, first, the stations with meaningful variance difference between solid precipitation values of SYNOP were specified (those stations without significant variance difference were excluded), and then the SYNOP were compared in pairs. The results of this comparison are presented in Table 3; in addition, the hours with significant differences are also presented. For example, Tabriz station has significant difference at error level of 5% at 15:00 and 00.00, 03:00, 06:00, 09:00, 18:00, and 21:00 UTC and Meshkinshar station at 00:00 and 06:00 UTIC. The difference between the SYNOP of Tabriz station can be seen in Fig. 4, where the vertical axis shows the mean frequency of solid precipitation in each SYNOP and the horizontal axis shows eight SYNOP for each station (Fig. 5).

Conclusion

The study of the solid precipitation trend of Northwestern Iran (1951–2018) showed that almost 85% of stations have a declining trend at an annual scale. Maragheh station with the highest negative trend as well as Mahabad station constitute the declining solid precipitation pole at the center of the area. These declining trends decrease when moving toward the northeast and northwest. In this study, the solid precipitation trend in Khoy and Parsabad stations is non-meaningfully positive at the annual scale which is consistent with the results of the Heydari study (2016). On the other hand, the results of this study are consistent with the research of Khalili et al. (2016). As in both studies, a decreasing trend of solid precipitation is observed.

On an hourly scale, 127 out of 152 studied SYNOP have a declining trend in which is more frequent in some hours; e.g., the highest decrease in solid precipitation in the region is seen at 15:00. Moreover, there are some differences in the trend between the SYNOP of each station. The variance analysis of these differences indicates that Kaleybar, Tabriz, Khoy, Uremia, and Ardabil have the highest meaningful difference

Table 3 The results of pair comparison of the SYNOP of stations (error level of 5%)

Synop Station	00	03	06	09	12	15	18	21
Ardabil	12	09	12	3	00	00		12
	15	12			03	03		
		15			06			
					21			
Urmia	06		00		06	06	06	06
			12					
			15					
			18					
			21					
Ahar			12		06			
Piranshahr			18				06	06
			21					
Tabriz	15	15	12	15	06	00	06	06
			15			03	15	15
			18			06		
			21			09		
						18		
						21		
Khoy	15	09	15	03	03	00	00	00
	18	12	18			03	03	03
	21	15	21			06	06	06
		18						
		21						
Kaleybar	03	00	00	00	00	00	03	03
	06	18	18	18	18	18	06	06
	09	21	21	21	21	21	09	09
	12						12	12
	15						18	15
Meshkinshahr	06							

at different hours of the day. However, it is not true for all stations, and almost 74% of the stations at Northwestern Iran do not show meaningful variance difference between SYNOP. Despite the mentioned hourly differences, no meaningful difference was observed in frequency and trend of solid precipitation (except 3 stations) during day and night and data analysis shows that the frequency of solid precipitation at Kaleybar station has the highest significant difference in the day.

The study of the relation between solid precipitation and altitude is the other result of this study which is interesting from two viewpoints: (Avanzi et al. 2014) negligible increase in solid precipitation frequency with altitude and (Bagherpour et al. 2017) increase of variation trend with increase in altitude, which follows Q = 0.00h−5 (h is height in meter and Q is

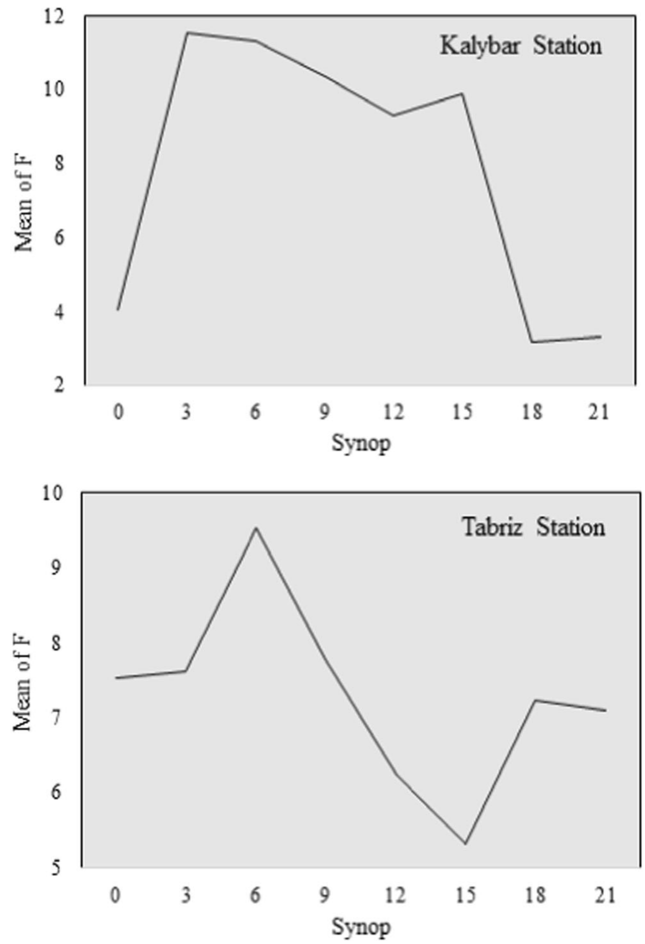

Fig. 4 The mean frequency of solid precipitation between Kaleybar and Tabriz stations in eight SYNOP

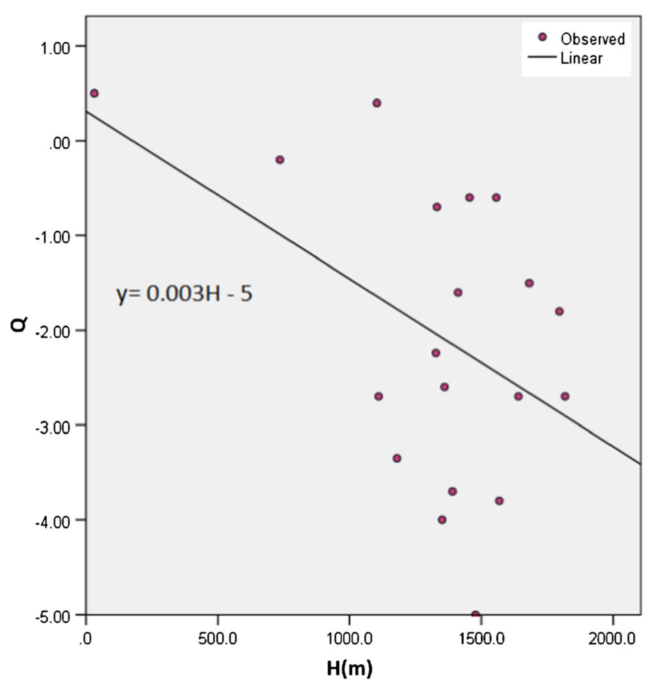

Fig. 5 The correlation diagram between height and MK statistics

MK statistics). Therefore, it can be argued that the decreasing trend of solid precipitation of the elevated stations is higher. Finally, the correlation between various SYNOP was calculated, and the results show that most SYNOP have a positive and significant correlation at reliability of 99% in the area.

Declarations

Conflict of interest The authors declare that there are no conflicts of interest regarding the publication of this paper.

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