Analysis of seasonal precipitation trend based on different quantiles in northern Iran

K. Solaimani1 · S. Bararkhanpour Ahmadi2

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Abstract
Climatic events are often caused by extreme meteorological conditions. Therefore, analyzing the changes trend in the mean or median data does not provide considerable information and it is necessary to examine it in different parts of the data distribution. Quantile regression method is able to study the trend in different quantiles of climatic parameters. In this study, the seasonal changes trend was analyzed using the quantile regression method in different amounts of daily precipitation for different at Gorgan, Babolsar and Anzali stations located in northern Iran. First, the statistical period of 62 years (1959–2020) was used to study the trend and then this given reach was divided into two statistical periods of 31 years (1(1959–1989) and 2(1990–2020)) and then Quantile regression was performed for different quantiles of daily precipitation for all three statistical periods. The results show different trend patterns for each quantile of seasons. Increasing trends have often been related to the extreme upper quantile of precipitation (the quantile 0.99), which indicates an increase in extreme rainfall and flood events. The slopes of increasing and decreasing trend have been changed in different time periods and also extreme precipitation have increased in winter in recent decades. The trend of precipitation slopes in semi-humid areas (Gorgan station) and in humid parts (Anzali station) were exposed more than temperate in period 2 and period 1, respectively. In conclusion, the highest increasing trends of precipitation were observed in autumn and winter and the highest decreasing trends were observed in spring and summer.

Keywords Precipitation · Quantile · Regression · Northern Iran

Introduction
Precipitation is the most significant component of the water cycle for human life. With global warming, the increasing number and intensity of extreme precipitation events are a global trend (Wu et al. 2021). Many studies have estimated the sensitivity of mean and extreme precipitation to warming (Kharin et al. 2013; Zhang et al. 2013). The extreme precipitation and its related impacts, especially flooding, significantly can affect the lives such as property, infrastructure damages, transportation disruption and also storm water pollution (Rappaport 2014; Sun and Lall 2015). Also, temporal and spatial changes in rainfall, which are the main source of flood and drought risks, have been expressed as one of the main effects of global warming (Solaimani 2021). Meanwhile, extreme climates and climatic events have considered by most climatologists in recent decades due to their severe potential effects on human life, economy and natural ecosystems. In addition, rainfall deficit and consequently lower runoff will reduce water resources and widespread droughts and in contrast, heavy rains have caused a rapid increase in discharge, which will cause a lot of economic and social damages in the agricultural, livelihood and infrastructure sections and causes serious disruption in regional development plans (Baba’eyyan et al. 2013). A combination of enhanced heavy precipitation amounts and reduced water infiltration capabilities of a dry soil may severely increase river peak discharges and flood-related risks in this region (Kyselý and Beranová 2009). Regarding the fact that extreme events such as droughts influence several different aspects of human life, susceptible environments and available water resources, especially in arid and semi-arid regions such as Iran (Amini et al. 2020), it is important to have long-term predictions to these extreme disasters in order to minimize risks.
method to identify changes from each quantile of weather variables. The above methods and can be an alternative trend detection method which does not have the limitations of the above methods and can be an alternative trend detection method which does not have the limitations of the above methods. This method also provides a more complete description of the long-term variability of a time series and is especially useful in series where extreme values are important (Lee et al. 2013). Compared to other parametric and nonparametric methods, the quantile regression method is able to identify changes in a distribution function in each quantile and can prevent the effects of cross and serial correlations in time series (Tan and Shao 2016). Also, by applying the quantile regression method, allows the user to examine the relationship between a set of variables and the different parts of the response distribution (Benoit and Poel 2017). Various studies have been conducted to study the precipitation trend using quantile regression methods in different parts of the world (So et al. 2012; Shiau and Huang 2015; Roth et al. 2015; Fan and Chen 2016; Shastri et al. 2017; Tharu and Dhakal 2018; Bohliger and Sorteberg 2018; Pumo and Noto 2021; Treppiedi et al. 2021; Onderka and Pecho 2021). Also, Tan et al. (2019) in modeling the changes in winter rainfall distribution in Canada concluded that in some stations in Eastern Canada, the distributional changes in winter rainfall are shown as an increase in the upper and lower quantiles. Abbas et al. (2019) in analyzing the long-term trend of rainfall records in two climatically different regions, they found that the quantile regression method can provide patterns for both extremely wet and dry conditions of the areas. Mohsenipour et al. (2020) examined changes in rainfall distribution during the monsoon months (June to September) in Bangladesh using quantile regression and the results showed that the amount of rainfall in many quantiles decreased from June to August and increased in September in most stations, and also the decrease in lower quantiles of rainfall in most of the monsoon months may cause an increase in the probability of droughts in the country. Kalisa et al. (2021) investigated the temporal-spatial variability of arid and wet conditions in East Africa from 1982 to 2015 using quantile regression on precipitation data. The results indicate significant variations in extreme wet and dry conditions across eight ecological zones in East Africa with variable slope along various quantiles. In this study, in order to investigate the seasonal changes trend of daily precipitation in different periods in Gorgan, Babolsar and Anzali synoptic stations, Iran, the quantile regression method was used to investigate the presence or absence of trends in different quantiles from precipitation data and the amount of precipitation changes in different quantiles.

Materials and methods

The study area

The study area is located in the southern Caspian coasts (northern Iran), which includes three provinces of Golestane, Mazandaran and Gilan (Fig. 1). The climate of northern Iran is Mediterranean with a temperate and humid climate. For each province one station was selected with the longest statistical
period (62 years of Gorgan, Babolsar and Anzali stations). The average annual rainfall varies between 1815 mm in the west and 60 mm in the east. The average annual temperature is between 15 and 18 degrees Celsius (Table 1). Forest cover, productive lands for horticulture and agriculture are natural features has formed this region into the agricultural pole of Iran.

Datasets

In this study, the time series of daily precipitation data in Gorgan, Babolsar and Anzali synoptic stations were used in the 62-year statistical period between 1959 and 2020. The used data were obtained from the Meteorological Organization of the Mazandaran province, Iran. After reviewing the data, three time periods of 1959–2020, 1959–1989 and 1990–2020 were considered to examine the trend. Thus, first the changes trend of precipitation for the total 62-year period was examined, then this period was divided into two 31-year periods and the changes trend for each period was examined separately. Daily rainfall time series in different seasons as well as annual scale was formed and quantile regression were applied to seasonal series of daily precipitation for each time period in all quantiles. In order to investigate the trend and precipitation changes in different quantiles of the precipitation variable, the amount of slope and the significance of the trend in quantiles of 0.01, 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0.95 and 0.99 of quantile regression lines were analyzed for all 3 statistical periods.

Quantile regression method

Quantiles are values with equal distances that are selected from the cumulative distribution function of a random variable. For the random variable \( x \), the \( \mu_p \) parameter is called the quantile \( p \)th for \( F(x) \) when the following inequality is established:
\[ P(x < \mu_p) \leq p \leq P(x \leq \mu_p), 0 < p < 1 \] (1)

The quantiles are more general than median such that \( P(0.5) \) is the median. In other words, if a line parallel to the y-axis is drawn from the point \( \mu_p \), the area under the frequency curve to the left of this line is equal to \( P \) (Fatahi 2005).

**Quantile regression**

Quantile regression is a trend-detection method which is used to identify any percentile value of climate variable over time (Wu et al. 2021). Quantile regression is a statistical method with the ability to calculate and plot different regression curves and correspond to different percentile points. This method is designed to model the quantiles of a response variable on conditional independent variables or over time and provides more information on how events related to limit and intensity values change. In hydrometeorological studies, the extreme quantiles (the 5th or 95th percentile) or the mean quantiles of quantile regression (the 50th quantile) are similar to the quantiles of response variables, which have been widely concerned by researchers (Yu et al. 2003).

The quantile regression model is in the form of Eq. (2):

\[ Y(\rho|x) = \beta_0(\rho) + \beta_1(\rho)x + \epsilon \] (2)

where \( \beta_0(\rho) \) is the intercept, \( \beta_1(\rho) \) is the slope coefficient and both vary depending on the value of the \( \rho \)th quantile being considered. \( \epsilon \) is the error with the expectation of zero and the range of \( \rho \) value is from 0 to 1 (Lee et al. 2013). To estimate quantile regression, unlike the linear regression model, which is based on minimizing the square of the residuals of the model, this regression method uses the minimization of the total absolute value of the residuals, which is called the Least Absolute Deviation (LAD) method. Accordingly, the estimation of \( \rho \)th quantile regression is performed by minimizing Eq. (3):

\[
\text{minimize} \left\{ \sum_{i: y_i \leq \rho y_p(x_i)} (1 - \rho) |y_i - \rho y_p(x_i)| + \sum_{i: y_i > \rho y_p(x_i)} \rho |y_i - \rho y_p(x_i)| \right\}
\]

(3)

where \( i = 1, 2, ..., n \), \( y \rho y_p(x_i) = \beta_0(\rho) + \beta 1(\rho)x_i \). In other words, the absolute value of the difference between an observation \( y_i \) and the corresponding \( \rho \)th quantile \( y \rho y_p(x_i) \) is weighted by \((1 - \rho)\) if the observation is below the quantile line and by \( \rho \) if the observation is above the line (Lee et al. 2013). The fitted line in this method is such that \( 0 \times 100\% \) of the points below it and the rest are above the line.

The estimation of the parameters \( \beta_p \) is in the form of Eq. (4):

\[ \hat{\beta}_p = \arg\min \sum_{i=1}^{n} \rho_p (y_i - x^T \beta) \] (4)

where the function \( \rho_p(\cdot) \) is defined as Eq. (5) (Koenker 2005):

\[ \rho_p(u) = \begin{cases} u(p - 1) & \text{if } u < 0 \\ u \rho & \text{if } u \geq 0 \end{cases} \] (5)

A bootstrap method is applied to evaluate the slope of each quantile and the uncertainty about the estimation of the slope of the quantile and allows a distribution of slope values to be obtained instead of an accurate unit estimate. Quantile regression model parameters, which include intercept and slope coefficients as well as estimation of standard errors, confidence intervals, t-statistic and significance for these coefficients, are performed by quantreg software package (http://cran.r-project.org/web/packages/quantreg/quantreg.pdf) (Koenker 2006).

**Results and discussion**

**Investigating the seasonal changes trend in precipitation for different statistical periods**

Quantile regression was performed on the time series of precipitation data for different seasons and for all three time periods. The trend slopes were estimated for 0.01 to 0.99 quantiles in increments 0.01, which includes 0.01, 0.02, 0.03, ..., 0.99 quantiles and significant slopes were identified at significance levels of 1, 5 and 10%. Then, the equivalent precipitation for each quantile was extracted and according to the regression relationship that was estimated for each quantile. The amount of changes (mm) was calculated and the results were analyzed for all three statistical periods in the equivalent precipitation related to each quantile.

**Total 62-year statistical period (1959–2020)**

The results of the quantile regression method for the daily rainfall time series in the period of 1959–2020 for different seasons are shown in Fig. 2 and Table 2. In Fig. 2 which shows the trend slope lines for each quantile, the black circles represent the precipitation data time series and the blue, green and purple lines, from top to bottom, belong to the quantiles of 0.01, 0.05, 0.1, 0.25, 0.75, 0.9, 0.95 and 0.99 in Babolsar, Gorgan and Anzali stations, respectively and also the red line corresponds to the slope line of the median quantile (0.5).

According to Fig. 2a, the estimated slope values for different quantiles of each season have changed in Babolsar station.
lower quantiles (<0.5) had no considerable change for seasons of the year but the 0.5 quantile indicated very little change. However, the upper quadrant lines (>0.5) in the spring, had a negative slope in the quantiles 0.75 and 0.9, but a positive slope in the extreme upper quantiles (0.95 and 0.99) where the slope value in the quantile 0.99 presents more. In contrast, the upper quantile lines (0.9 and 0.95) had a negative slope in summer and autumn but the upper quantile 0.99 indicated with a positive slope. However, the upper quantiles had a positive and increasing trend in winter. Therefore, it can be specified that very high amounts of precipitation (quantile 0.99) in all seasons have increased significantly, while very low amounts of precipitation (quantile 0.01) has not considerable changes. Also, the shorter distance between the quantile regression lines on the right side of the graph indicates that the daily precipitation distribution in spring, summer and winter are with a negative skewness. For Gorgan and Anzali stations (Fig. 2b, c), the lower quantile lines (<0.5) had very low trend slopes in all seasons and there was no significant trend in the median of the data. However, the upper quantile lines (>0.5), especially the extreme upper (0.99), has indicated with a noticeable trend slopes. Quantile regression lines for Gorgan station (Fig. 2b), in the upper quantiles, shown an increasing trend in summer, autumn and winter but a decreasing trend in spring which is slightly higher (0.99) in the upper quantiles. Therefore, it can be supposed that very high amounts of precipitation increase are visible in summer, autumn and winter, but shows a reduction in spring. However, for Anzali station (Fig. 2c), the quantile regression lines be situated smoother and the slopes of the trend in the upper quantiles were less than the slopes of the trend in Gorgan and Babolsar stations. In spring and summer, the intensity of trend slopes was considerably lower and only the upper middle quantiles (0.95 and 0.9) had a decreasing trend. The extreme upper quantile (0.99) had a noticeable decreasing trend in autumn and a noticeable increasing trend in winter, which indicates that very high amounts of precipitation reduced in autumn and increased in winter. Also, the distribution of precipitation in Gorgan station had negative skewness for summer, autumn and winter seasons but a positive skewness in spring. Whereas, in Anzali station, data distribution shows a positive and negative skewness in autumn and winter, respectively.

Table 2 shows the equivalent, the trend slope and the amount of changes in precipitation for each quantile in season separately. For Babolsar station, in spring, only the extreme upper quantile 0.99 had a significant increasing trend with a positive slope, which indicates a significant increase of 17.8 mm in the amounts of precipitation with 43.5 mm. However, in summer, the median quantile 0.5 exposed a significant increasing trend, which indicates that the amount of precipitation 6 mm in summer has increased by 2.4 mm. On the other hand, no significant trend has been observed in autumn. However, the upper quantiles 0.75, 0.9 and 0.95 had a significant increasing trend in winter, which according to the equivalent precipitation of every quantile, it can

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Fig. 2 Quantile regression slope lines in different quantiles (0.01, 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0.95 and 0.99) from daily precipitation data in the different seasons at Babolsar (a), Gorgan (b) and Anzali (c) stations for the years 1959–2020
be supposed that the quantities of precipitations of 14, 24 and 30 mm in winter has increased by 3, 6.3 and 7.68 mm, respectively. For Gorgan station, low and median amounts of precipitation (lower and median quantiles) in spring have reduced significantly and its maximum value shows in 9 mm, which decreased by 2 mm. In summer, quantiles 0.05 and 0.9 of precipitation had significant decreasing and increasing trends, respectively, which indicates that the amount of precipitation of 1.3 mm by 1.19 mm decreased but in contrast, the amount of precipitation of 17 mm increased by 7.79 mm. The extreme lower quantiles and the middle quantiles have decreased significantly in autumn, with the highest slope being related to the 0.75 quantile, which indicates a decrease of 15 mm by 11 mm. However, in winter, the upper and extreme upper quantiles (0.9, 0.95 and 0.99) had a significant upward trend with a significant slope, which indicates values of 17.05, 22.8 and 32.3 mm which increased by 3.93, 8.91 and 26.22 mm, respectively. But for Anzali station, the quantity of significant trends of precipitation has shown

| station | Season | Equivalent precipitation (mm) | Quantile regression in different quantiles |
|---------|--------|-------------------------------|------------------------------------------|
|         |        | 0.01 | 0.05 | 0.1 | 0.250 | 0.5 | 0.75 | 0.9 | 0.95 | 0.99 |
| Babolsar Spring | 1 | 1.2 | 1.4 | 2 | 4 | 9.2 | 18.3 | 25.4 | 43.5 |
|         | Trend slope (mm/decade) | 0 | -0.003 | -0.006 | 0 | -0.01 | -0.03 | 0 | 0.013 | 0.3 |
|         | Precipitation changes (mm) | 0 | -0.17 | -0.35 | 0 | -0.6 | -1.6 | 0 | 7.6 | 17.8 |
|         | Summer | 1 | 1.4 | 2 | 3 | 6 | 14 | 29 | 43 | 75.7 |
|         | Trend slope (mm/decade) | 0 | -0.002 | 0 | 0.009 | 0.04 | 0.03 | -0.06 | -0.065 | 0.37 |
|         | Precipitation changes (mm) | 0 | -0.1 | 0 | 0.6 | 2.4 | 1.8 | -3.8 | -3.94 | 22.22 |
|         | Autumn | 1.1 | 2 | 2 | 4.2 | 11 | 24.5 | 45 | 61.6 | 107 |
|         | Trend slope (mm/decade) | 0 | 0.002 | -0.002 | 0.0003 | 0 | -0.05 | -0.04 | 0.08 |
|         | Precipitation changes (mm) | 0 | 0 | 0.12 | -0.1 | 0.02 | 0 | -3.07 | -2.36 | 4.54 |
|         | Winter | 1.1 | 2 | 2 | 3 | 7 | 14 | 24 | 30 | 46 |
|         | Trend slope (mm/decade) | 0.003 | -0.009 | 0 | 0.002 | 0 | 0.05 | 0.1 | 0.13 | 0.16 |
| Gorgan Spring | Precipitation changes (mm) | 0.18 | -0.54 | 0 | 0.1 | 0 | 3 | 6.3 | 7.68 | 10 |
|         | Spring | 1.0968 | 1.375 | 1.7 | 2.4 | 4.6 | 9 | 17 | 26 | 45.12 |
|         | Trend slope (mm/decade) | -0.005 | -0.014 | -0.013 | -0.019 | -0.03 | -0.036 | -0.045 | -0.09 | -0.27 |
|         | Precipitation changes (mm) | -0.31 | -0.84 | -0.80 | -1.13 | -1.74 | -2.11 | -2.68 | -5.24 | -16 |
|         | Summer | 1.0118 | 1.3 | 2 | 2.02 | 4.2 | 9 | 17 | 24.9 | 40 |
|         | Trend slope (mm/decade) | -0.006 | -0.02 | -0.01 | -0.003 | -0.02 | 0 | 0.13 | 0.12 | 0.2 |
|         | Precipitation changes (mm) | -0.35 | -1.19 | -0.54 | -0.18 | -1.20 | 0.00 | 7.79 | 6.96 | 10.93 |
|         | Autumn | 1.1 | 1.855 | 2 | 3 | 6.95 | 15 | 27 | 36 | 52.14 |
|         | Trend slope (mm/decade) | -0.008 | -0.013 | 0 | 0 | -0.044 | -0.09 | -0.064 | 0 | 0.35 |
|         | Precipitation changes (mm) | -0.47 | -0.76 | 0.00 | 0.00 | -2.62 | -5.34 | -3.77 | 0.00 | 20.73 |
|         | Winter | 1.1 | 1.5 | 2 | 3 | 5.4 | 11 | 17.05 | 22.8 | 32.3 |
|         | Trend slope (mm/decade) | -0.003 | -0.015 | -0.004 | 0 | -0.015 | -0.013 | 0.067 | 0.15 | 0.44 |
|         | Precipitation changes (mm) | -0.18 | -0.88 | -0.25 | 0.00 | -0.91 | -0.80 | 3.93 | 8.91 | 26.22 |
| Anzali Spring | Equivalent precipitation (mm) | 1.01 | 1.2 | 1.6 | 2.4 | 5 | 11 | 21 | 31.8 | 53 |
|         | Trend slope (mm/decade) | 0 | -0.004 | -0.014 | 0.004 | 0 | -0.05 | -0.11 | -0.16 | -0.05 |
|         | Precipitation changes (mm) | 0.00 | -0.23 | -0.83 | 0.25 | 0.00 | -3.03 | -6.83 | -9.52 | -3.16 |
|         | Summer | 1.01 | 2 | 2 | 4 | 11.25 | 26 | 51 | 74 | 118.6 |
|         | Trend slope (mm/decade) | 0 | 0 | 0 | -0.01 | 0.056 | 0.15 | 0.17 | 0 | 0.06 |
|         | Precipitation changes (mm) | 0.00 | 0.00 | 0.00 | -0.57 | 3.29 | 9.18 | 10.00 | 0.00 | 3.37 |
|         | Autumn | 1.1 | 2 | 2.2 | 5.155 | 14 | 34 | 60 | 79 | 125 |
|         | Trend slope (mm/decade) | 0 | 0 | 0.012 | 0.014 | 0.03 | -0.02 | -0.09 | -0.23 | -0.6 |
|         | Precipitation changes (mm) | 0.00 | 0.00 | 0.71 | 0.80 | 1.70 | -1.11 | -5.53 | -13.41 | -35.84 |
|         | Winter | 1.013 | 1.4 | 2 | 4 | 8.7 | 18.3 | 31 | 42 | 67.56 |
|         | Trend slope (mm/decade) | 0 | -0.016 | -0.003 | -0.02 | -0.014 | -0.023 | -0.07 | -0.11 | 0.14 |
|         | Precipitation changes (mm) | 0.00 | -0.96 | -0.18 | -1.12 | -0.84 | -1.37 | -4.07 | -6.36 | 8.19 |

Values in **bold** are significant in significance level < 0.1
fewer in different seasons. In spring, 0.1 and 0.95 quantiles had a significant decreasing trend, indicating a decrease in precipitation of 1.6 and 31.8 mm by 0.83 and 9.5 mm, respectively. While the middle quantiles (0.5 and 0.75) in summer and the lower quantile (0.1) in autumn, have a significant upward trend that the maximum value of the trend slope was 26 mm in summer by 9.18 mm. However, in winter, there are significant and decreasing trends in the lower quantiles (0.25 and 0.5), which are relatively less.

The first 31-year statistical period (1959–1989)

The results of trend slope lines for the period 1959–1989 in Babolsar station (Fig. 3a) have shown that trend slope lines are dissimilar in different quantiles and the upper quantiles (> 0.5) have more slope than the lower quantiles (< 0.5). In summer and autumn, most of the precipitation quantiles had an increasing slope and only the lower quantile 0.05 in summer and the middle quantiles of 0.25 and 0.5 in autumn had a negative and decreasing trend. But in spring, the lower quantile (0.1 and 0.05) and upper quantile lines (0.75 and 0.9) had a decreasing trend slope, while the upper quantile lines (0.95 and 0.99) had a higher trend slope. Therefore, it can be stated that very high amounts of precipitation in the spring have a noticeable increasing trend. However, in winter, all quantiles had a positive and increasing trend slope, with the highest amount of slopes belonging to the upper quantiles (0.75, 0.9 and 0.95). The distance between the quantile lines for the spring, summer, and autumn seasons to the left of the graph or in the early years of the precipitation data is less, indicating that the precipitation data distribution in these seasons had a negative skewness. The results for Gorgan and Anzali (Fig. 3b, c) stations are indicated that the lower and median quantiles (0.5 < 0.5) have a very low trend slope. The extreme upper quantiles for Gorgan (Fig. 2b) station had a lower trend slope in summer and autumn, but the upper middle quantiles (0.95 and 0.9) had an increasing trend in summer and a decreasing trend in autumn. However, the trend slopes in the upper quantiles were higher for spring and winter, so that in spring, the trend was decreasing and there was an increasing trend in winter, that the intensity of decreasing and increasing slopes has been more in extreme upper quantiles. Therefore, it can be concluded that higher amounts of precipitation reduction in spring with high intensity but with a trend of increase in winter. However, the trend slopes at Anzali station (Fig. 2c) indicates higher than the total period of 62 years. Upper quantiles of precipitation (> 0.5) increased at high rates in spring and winter but decreased in summer and autumn. The amount of skewness in the distribution of precipitation data in Gorgan is less and the most skewness is in spring as positive.
For Anzali station, the distribution of precipitation data in spring and winter has a negative skewness and in summer and autumn has a positive skewness.

Significance of trend slope in the period of 1959–1989 (Table 3) has shown that in spring, the extreme lower quantile of 0.05 shown a significant decreasing trend and the extreme upper quantile of 0.99 specified a significant increasing trend that due to their equivalent precipitation and the amount of changes have indicated the amount of daily precipitation of 1.2 mm with significant decreasing by 0.38 mm and in contrast, the amount of precipitation 39.7 mm in this season has increased by 14.5 mm. Generally, it can be assumed that very wet and dry conditions are increasing in this season. In summer, the lower quantile 0.05 has a significant decreasing trend, which indicates a decrease in precipitation 1.7 mm by 0.26 mm. In contrast, the upper quantiles of 0.9 and 0.95 shown a significant increasing trend, which according to their equivalent precipitation and the amount of changes, it can be supposed that the amount of precipitation 31.4 and 82.9 mm in summer, has increased by 17.24 and 29 mm, respectively. In autumn, quantiles 0.1 and 0.99 and in winter, quantiles 0.25 and 0.75 exposed a significant increasing trend, which can be concluded that the precipitation values of 2 and 111.56 mm in autumn are increased by 0.12 and 58 mm, respectively. Also the precipitation values of 3 and 13 mm in winter are increased by 0.22 and 4.3 mm, respectively. In Gorgan station, lower (0.5 and 0.01), middle (0.25 and 0.5) and upper (0.95) quantiles in the spring, lower (0.05 and 0.01) quantiles in the summer and the lower (0.01) and upper (0.9) quantiles in autumn, shown a significant decreasing trend with a negative slope, the highest value of the trend slopes, related to precipitation 26 mm in spring and 28 mm in autumn, which decreased by 9.96 and 9.33 mm, respectively. However, there is a significant increasing trend in winter only in the lower quantile of 0.05, which indications that the amount of precipitation 2 mm has decreased by 0.73 mm. In Anzali station, the number of significant trends in different seasons is less than other stations and only upper quantile 0.9 in spring, quantile 0.25 in summer and lower quantiles 0.05 and 0.01 in winter, exposed a significant decreasing trends where the highest trend slope was related to precipitation 23 mm in spring and precipitation 4 mm in summer, which has decreased by 10.5 and 2, respectively.

The second 31-year statistical period (1990–2020)

The results of quantile regression on 31-year precipitation data from the statistical period of 1990–2020 in Babolsar station (Fig. 4a) showed that, as in previous periods, the slopes in different quantiles from each season were different. In spring, the quantile slope lines have shown decreasing in most cases, but the upper quantiles (0.9 and 0.95) specified an increasing slope and the amount of slopes in the upper quantiles exposed more than the lower quantiles (Table 4), but only quantile of 0.25 indicated a significant decreasing trend. Therefore, it can be expected that the amount of precipitation 1.3 mm has decreased by 0.75 in the spring. In summer, most of the quantiles shown an increasing trend but only the upper quantile of 0.9 indicated a decreasing trend. However, no significant trend observed in any quantiles. In autumn, a number of lower (0.01, 0.05) and upper quantiles (0.75, 0.9, 0.95) specified a decreasing trend, but other quantiles shown an increasing trend. However, only the lower quantile of 0.05 shown a significant decreasing trend and the lower quantile of 0.01 indicated a significant increasing trend. Therefore, considering the equivalent precipitation of these two quantiles, it can be supposed that the amount of precipitation 2 mm decreased by 0.35 but the amount of precipitation 2.1 mm increased by 0.17 mm, significantly. In winter, the amount of increasing slopes was more than the amount of decreasing slopes. The lower and median quantiles had a decreasing trend and the upper quantiles had an increasing trend in daily precipitation. However, only the lower quantiles of 0.05 and 0.1 had a significant decreasing trend and the upper quantiles of 0.95 and 0.99 had a significant increasing trend, which shows that the amount of precipitation 1.5 and 2 mm in winter, decreased by 0.7 and 0.62, respectively, but in contrast, the amount of precipitation 32.7 and 47.5 mm increased by 7.95 and 24.34 mm, respectively. Also, considering the distance between quantile regression lines in each season, shown that the precipitation data distribution has negative skewness in winter and positive skewness in spring, but the amount of skewness was less in summer and autumn. The values of trend slopes in the upper quantile lines (>0.5) in Gorgan and Anzali stations (Fig. 4b, c) specified higher than the previous periods. In Gorgan station (Fig. 2b), the upper quantiles, especially the extreme upper (0.99), identified with an increasing and significant trend in spring, autumn and winter, and the distribution of precipitation data in these seasons specified with a negative skewness. However, the upper quantiles of precipitation in summer has a decreasing trend, especially in the extreme quantiles, and the summer rainfall distribution recognized with a positive skew. Therefore, based on the gained results very high amounts of precipitation have decreased at high rates in spring, autumn and winter. However, in Anzali station (Fig. 2c), upper quantiles of precipitation, especially extreme upper quantile (0.99), has increased in all seasons and the distribution of rainfall data in all 4 seasons shows a negative skew.

For Gorgan station (Table 4), only the extreme upper quantile of 0.99 in spring, and the upper quantile of 0.9 in summer, recognized with a significant decreasing trend, and the extreme upper quantile of 0.99 in autumn, had a significant increasing trend which indicates that the amount of precipitation 41.6 mm in spring and 17.4 mm in summer, was decreased by 3.33 and 12 mm, respectively. In contrast, the amount of precipitation 57.2 mm was increased by 50 mm in autumn. However, in winter, the extreme upper quantiles (0.9, 0.95 and 0.99) have increased significantly, which according to the equivalent precipitation the amounts of precipitation 18 mm, 23.6 mm and 40.55 mm have increased by 8.97, 14.35 and 39.43 mm,
respectively. For Anzali station, the values of significant trends were relatively lower than the previous periods and no significant trends were observed in spring, summer and autumn. But in winter, only the lower quantile 0.1 and the upper quantile 0.99 had a significant upward trend with a positive slope, which is higher in the quantile 0.99. Therefore, the amount of precipitation 61.65 mm in this season has increased by 28.75 mm significantly.

According to the above results, the quantile regression method provides more information than nonparametric tests based on mean data in the study of precipitation changes. The trends detection using the quantile regression method were overlooked by other previously used approaches (Tharu and Dhakal 2020). Studies on the precipitation trend in northern parts of Iran, in most cases have shown a decreasing trend or no trend (Ebrahimi and Kardavani, 2014; Ghaedi and Shojaian, 2020; babolhekami et al. 2020). While the quantile

| Station | Season | Equivalent precipitation (mm) | 0.01 | 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 0.9 | 0.95 | 0.99 |
|---------|--------|--------------------------------|------|------|-----|------|-----|------|-----|-----|-----|
| Babolsar| Spring | Trend slope (mm/decade)        | 0    | 0    | 0   | -0.013 | 0   | -0.03 | -0.17 | -0.15 | 0.06 |
|         |        | Precipitation changes (mm)     | 0    | 0    | -0.38 | -0.48 | 0   | -0.87 | -4.83 | -4.35 | 1.7  |
|         | Summer | Equivalent precipitation (mm)  | 1    | 1.7  | 2    | 2.7  | 5   | 14   | 31.4 | 44.5 | 82.9 |
|         |        | Trend slope (mm/decade)        | 0    | 0    | -0.009 | 0   | 0.017 | 0.04 | 0.3  | 0.64 | 0.59 |
|         |        | Precipitation changes (mm)     | 0    | 0    | -0.26 | 0.48 | 1.26 | 8.83 | 18.64 | 17.24 | 29   |
|         | Autumn | Equivalent precipitation (mm)  | 1    | 2    | 2    | 5    | 11  | 24.3 | 46   | 64   | 111.56 |
|         |        | Trend slope (mm/decade)        | 0.0064 | 0 | 0.004 | -0.017 | -0.08 | 0.08 | 0.2  | 0.6  | 2    |
|         |        | Precipitation changes (mm)     | 0.19 | 0    | 0.012 | -0.5  | -2.23 | 2.23 | 6.2  | 17.84 | 58   |
|         | Winter | Equivalent precipitation (mm)  | 1    | 2    | 2    | 3    | 7   | 13   | 23   | 29   | 44.2 |
|         |        | Trend slope (mm/decade)        | 0.003 | 0    | 0    | 0.0074 | 0   | 0.14 | 0.11 | 0.27 | -0.022 |
|         |        | Precipitation changes (mm)     | 0.093 | 0    | 0    | 0.22  | 0    | 4.3  | 3.3  | 8.2  | -0.65 |
|         | Summer | Equivalent precipitation (mm)  | 1.2  | 1.6  | 2    | 3    | 5   | 9    | 17   | 26   | 45.77 |
|         |        | Trend slope (mm/decade)        | -0.02 | -0.03 | 0    | -0.03 | -0.06 | -0.09 | -0.2  | -0.35 | -0.53 |
|         |        | Precipitation changes (mm)     | -0.69 | -0.76 | 0.00 | -0.76 | -1.75 | -2.52 | -5.09 | -9.96 | -14.74 |
|         | Autumn | Equivalent precipitation (mm)  | 1.2  | 1.9  | 2    | 2.2  | 5    | 9    | 14   | 22   | 38.5 |
|         |        | Trend slope (mm/decade)        | -0.02 | -0.025 | 0    | 0.02  | 0    | -0.043 | 0.09 | 0    | -0.08 |
|         |        | Precipitation changes (mm)     | -0.65 | -0.70 | 0.00 | 0.49  | 0.00 | -1.22 | 2.55 | 0.00 | -2.15 |
|         | Winter | Equivalent precipitation (mm)  | 1.2  | 2    | 2    | 3    | 6   | 11   | 17   | 21.65 | 28.3 |
|         |        | Trend slope (mm/decade)        | -0.02 | 0    | 0    | 0    | -0.074 | -0.15 | -0.33 | -0.43 | -0.1 |
|         |        | Precipitation changes (mm)     | -0.66 | 0.00  | 0.00 | 0.00 | -2.06 | -4.14 | -9.33 | -12.13 | -2.55 |
|         | Summer | Equivalent precipitation (mm)  | 1.155 | 2    | 2.16 | 5    | 14   | 34   | 63   | 84.6 | 133.2 |
|         |        | Trend slope (mm/decade)        | 0.008 | 0    | 0.02 | 0.03 | 0.09 | 0.17 | 0.14 | 0.17 | -2   |
|         |        | Precipitation changes (mm)     | 0.23  | 0.00 | 0.46 | 0.74 | 2.55 | 4.67 | 4.00 | 4.76 | -57.65 |
|         | Winter | Equivalent precipitation (mm)  | 1    | 2    | 2.01 | 4    | 9    | 19   | 32   | 44   | 68.32 |
|         |        | Trend slope (mm/decade)        | -0.01 | -0.02 | -0.005 | 0    | 0    | 0    | -0.2 | 0.4  | -10.67 |
|         |        | Precipitation changes (mm)     | -0.25 | -0.64 | -0.13 | 0.00 | 0.00 | 0.00 | 0.00 | -6.00 | 10.67 |

Values in bold are significant in significance level < 0.1.
regression method has shown different trends (increasing and decreasing) in different statistical periods. In period 1 (62 years), the most significant increasing trends were for upper quantiles in spring and winter, which in spring, the quantile 0.99 mm increased by 14.8 mm and in winter, the quantile 0.75, 0.9 and 0.95 mm increased by 3, 6.3 and 7.8 mm, respectively. But in summer, only the middle quantile 0.5 increased by 2.4 mm, and also during the year, the quantile 0.05 decreased by 0.72 mm and the quantile 0.75 increased by 3.7 mm. In Gorgan station, the most significant trends are in the quantile 0.75, and in spring and autumn, and the highest upward trend slopes in the upper and extreme upper quantiles, for summer and winter seasons that intensity of the trend slopes is higher in winter. But in Anzali station, the most slopes of the decreasing and increasing trend have observed in spring (0.95) and summer (0.75), respectively. In the second period (first 31 years), in spring and summer, the extreme lower quantile 0.05 has a decreasing trend and the extreme upper quantile 0.99 has an increasing trend, which indicates an increase in precipitation in the quantile 0.99 in spring and summer by 14.5 and 29 mm, respectively and its reduction in quantile 0.05 by 0.38 and 0.26 in spring and summer, respectively. In autumn, quantiles 0.25 and 0.99 increased by 0.012 and 58 mm and in winter, quantiles 0.25 and 0.75 increased by 0.22 and 4.3 mm, respectively. For Gorgan station, the most significant trend slopes were in spring (0.95) and autumn (0.9), which has a significant decreasing trend. But in Anzali station, quantile 0.9 in the spring had the most significant decreasing trend. While, in other seasons, no significant trends have been observed. In time period 3 (second 31 years), in spring, the quantile 0.25 decreased by 0.75 mm but in autumn, the quantile 0.05 decreased by 0.35 mm and quantile 0.1 increased by 0.17 mm. In winter, the quantiles 0.05 and 0.1 decreased by 0.17 and 0.62 and quantiles 0.95 and 0.99 increased by 7.95 and 24.34 mm, respectively, but during the year, only quantile 0.1 has decreased by 0.27 mm. However, in Gorgan station, the most significant decreasing trends are in spring (quantile 0.99) and summer (quantile 0.9) and in contrast, the most significant increasing trends in autumn (quantile 0.9) and winter (quantiles 0.9, 0.95 and 0.99). While for Anzali station, there is a significant upward trend only in winter (quantile 0.99).

According to the results, the most changes in the precipitation trend are related to very high amounts of precipitation. In Babolsar station, in periods 1 and 3, high amounts of precipitation has increased in winter but in the period 2, it was belonged to spring, summer and autumn. For Gorgan station, the very high precipitation for periods 1 and 3 have increased in autumn and winter and for periods 2 and 3, have decreased in spring and summer. In other words, the increasing trend of precipitation is more in the rainy seasons and decreasing trend of precipitation is less in the low rainy seasons. But in Anzali...
station, the amounts of very high precipitation for periods 1 and 2, decreased in spring while, for period 3, increased in winter. Most of the trend slopes were specified for Babolsar and Anzali stations in period 2, but for Gorgan station in period 3. In general, based on the studied periods, the highest and lowest slopes of the trend were related to Gorgan and Anzali, respectively. Geographically, from the west to the east of Iran, the intensity of precipitation decreases and the weather temperature increases, so the effect of climate change in semi-humid regions has increased more sharply than in wet regions. Despite of the high temperature and lower rainfall in the eastern regions, the occurrence of heavy rainfall has increased in these areas, especially in the recently decades. Also, most of the floods for all regions were occurred in winter. Therefore, due to the climatic characteristics of this season (low temperature and high precipitation), increasing the intensity of rainfall may cause severe damage. Using quantile regression method will lead to better management results and decisions in controlling very low and

Table 4 Results of application of quantiles regression method on daily precipitation data in different seasons and stations for the period 1990–2020

| Station | Season | Equivalent precipitation (mm) | 0.01  | 0.05  | 0.1   | 0.25  | 0.5   | 0.75  | 0.9   | 0.95  | 0.99 |
|---------|--------|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| Babolsar| Spring | 1                              | 1.2   | 1.3   | 2     | 4     | 9.2   | 18.4  | 27    | 46.5  |
|         |        | 0.0037                         | -0.0064 | -0.02 | -0.043 | -0.045 | 0.1   | 0.52  | -0.33 |
|         |        | 0.0011                         | -0.2   | -0.75 | -1.3   | -1.34  | 3.2   | 15.7  | -10   |
|         | Summer | 1.05                           | 0.08   | 0.007 | 0.043  | 0.029  | -0.004 | 0.22  | 0     |
|         |        | 0.16                           | 0.03   | 0.023 | 1.3    | 0.9    | -0.012 | 6.75  | 0     |
|         | Autumn | 1.1                            | 2      | 2.1   | 4.8    | 11.1   | 25    | 44    | 62    | 107.8 |
|         |        | -0.004                         | -0.012 | 0.006 | 0.043  | 0.07   | -0.097 | -0.25 | -0.55 | 0.52  |
|         |        | -0.12                          | -0.35  | 0.17  | 1.26   | 2.03   | -2.03  | -7.25 | -16.1 | 15.2  |
| Gorgan  | Spring | 1.2                            | 1.5    | 2     | 3.1    | 7      | 14.8   | 26    | 32.7  | 47.5  |
|         |        | -0.004                         | -0.023 | -0.021 | 0.012 | -0.009 | 0.016  | 0.12  | 0.27  | 0.84  |
|         |        | -0.14                          | 0.00   | 0.12  | -0.43  | -0.94  | -2.30  | -6.26 | -1.67 | -3.33 |
|         | Summer | 1.01                          | 1.36   | 1.503 | 2.01   | 4      | 9      | 17.4  | 27    | 46.15 |
|         |        | 0.004                          | -0.012 | 0.003 | 0.044  | -0.02  | 0.04   | 0.02  | -0.4  | -0.35 | -1.3  |
|         |        | 0.00                           | 0.11   | -0.37 | 0.10   | 1.32   | -0.50  | -12.00 | -10.44 | -38.57 |
|         | Autumn | 1.1                            | 1.473  | 2     | 3      | 6.01   | 14     | 26    | 35.2  | 57.2  |
|         |        | -0.004                         | -0.02  | 0     | 0.001  | 0.007  | 0.013  | 0.3   | 1.7   |
|         |        | -0.13                          | -0.52  | 0.00  | 0.00   | 0.05   | -2.31  | 3.84  | 8.00  | 50.00 |
|         | Winter | 1.1                            | 1.3    | 1.8   | 2.9    | 5.15   | 10.02  | 18    | 23.6  | 40.55 |
|         |        | 0.005                          | 0.01   | 0.006 | 0.022  | 0.021  | 0.09   | 0.3   | 0.5   | 1.3   |
|         |        | 0.15                           | 0.30   | 0.19  | 0.65   | 0.62   | 2.74   | 8.97  | 14.35 | 39.43 |
| Anzali  | Spring | 1.01                          | 1.14   | 1.4   | 2.4    | 5      | 10.02  | 19    | 26    | 46.9  |
|         |        | 0.00                           | 0.005  | 0.02  | 0.04   | 0.04   | 0      | 0.04  | 0.64  |
|         |        | 0.00                           | 0.16   | 0.60  | 1.20   | 1.16   | 0.00   | 1.19  | 19.33 |
|         | Summer | 1.01                          | 2      | 2.01  | 4      | 12.9   | 29.01  | 56    | 74    | 118.6 |
|         |        | 0.008                          | -0.0007 | -0.025 | 0.06  | 0.23   | 0.1    | 0.2   | 1.1   |
|         |        | 0.00                           | 0.25   | -0.02 | -0.75  | 1.83   | 6.82   | 3.00  | 5.77  | 33.27 |
|         | Autumn | 1.1                            | 1.9    | 2.319 | 5.205  | 14     | 33     | 58    | 76    | 114.1 |
|         |        | 0.007                          | 0.022  | 0.04  | 0.08   | 0.13   | 0.04   | 0.12  | 0.64  |
|         |        | 0.00                           | 0.23   | 0.67  | 1.13   | 2.48   | 3.91   | 1.14  | 3.75  | 19.09 |
|         | Winter | 1.1                            | 1.3    | 1.8   | 3.205  | 8      | 18     | 29    | 39.28 | 61.65 |
|         |        | 0.005                          | 0.007  | 0.023 | 0.02   | 0.06   | 0.13   | -0.052 | 0.024 | 0.96  |
|         |        | 0.16                           | 0.20   | 0.70  | 0.48   | 1.75   | 4.00   | -1.56 | 7.09  | 28.75 |

Values in **bold** are significant in significance level < 0.1
Changes in precipitation occurred mostly in the upper quantiles, especially extreme upper quantiles, while the lower quantiles of precipitation had a negative or no trend slope in most stations and in all periods. The slope of the trend was higher for Babolsar and Anzali stations in period 2 and for Gorgan station in period 3. Also, the most slopes of significant decreasing trends were observed in spring and summer, but in contrast, significant increasing trends were often present in autumn and winter, which indicates an increase in drought and flood conditions.

Due to precipitation changes in different time periods and also on seasonal scales, climate change has happened or is occurring and it is necessary to carefully consider these changes, plan to adapt and reduce the damages caused by these changes.

Observing the increasing and decreasing trend slope in different quantiles of a time series in some seasons shows that climate change has occurred in such a way that irregularity has increased and although precipitation is decreasing in most quantiles or the trend is not significant, but flood days (extreme upper quantiles) have a significant increasing trend which is in conform with reports of floods in the region in recent years.

According to the results of the study, researchers are advised to use other statistical models to study changes in extreme precipitation and the factors affecting it in order to achieve more accurate results. Also, due to the increased probability of drought and flood conditions, strong infrastructure should be built to reduce runoff during floods and increase water storage for drought management.

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Declarations

Conflict of interest The authors declare that has no any conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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Conclusion

In this study, using the quantile regression model, the changes trend in different amounts of daily precipitation in different statistical periods (62 years and two periods of 31 years) was investigated on a seasonal scale for Babolsar, Gorgan and Anzali stations in northern parts of Iran. The evaluations showed that the quantile regression method is able to identify the status of changes in different precipitations. The conclusion of most important gained results on time series are as follows:

(1) Changes in precipitation occurred mostly in the upper quantiles, especially extreme upper quantiles, while the lower quantiles of precipitation had a negative or no trend slope in most stations and in all periods. The slope of the trend was higher for Babolsar and Anzali stations in period 2 and for Gorgan station in period 3. Also, the most slopes...
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