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Observed changes in the contribution of extreme precipitation over the Zagros Mountains, Iran

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Abstract— Due to global warming, precipitation regimes are expected to change, and heavy events are expected to occur more frequently. This study investigates the relative share of heavy daily precipitation events to total precipitation for past and current climates. In this regard, daily precipitation data with a spatial resolution of 0.25° × 0.25° from the APHRODITE and CHIRPS databases are used. We used two nonparametric tests, the Mann–Kendall test and Sen's slope estimator, to identify the trend. The results showed that the frequency of daily heavy precipitation has been increasing in most regions of Iran. The relative share of heavy daily precipitation events to total precipitation has increased over the southwest and central areas of Iran from a case of the past to the current climate. The rise in the share of heavy precipitation of the total precipitation has led to a decrease in the frequency of rainy days (wet days) and an increase in the intensity and concentration of precipitation in Iran. The amount of increase in the share of heavy rainfall to the total precipitation is more prominent in the middle parts of the Zagros Mountains. These conditions lead to heavy floods in the southwestern plains of Iran.

Key-words: extreme daily precipitation, Mann-Kendall test, trend analysis, Iran

1. Introduction

In general, a climate extreme event is defined as the occurrence of a weather or climate event above (or below) a certain threshold value near the upper (or lower) ends of the range of observed values of the variable. Extreme weather events (droughts, heavy rainfall, floods, and heatwaves) are a matter of great topical importance and interest in a variety of environmental and social situations (*Karimi et al.*, 2021). Compared to the average climate, extreme events have a much greater impact on human activity and natural environments (*Kunkel et al.*, 1999; *Easterling et al.*, 2000). The possible increase of extreme weather events both in frequency and intensity is among the predicted effects of climate change. Observational analysis has indicated that extreme climate events have exhibited an increasing trend in most areas of the earth in the past half century, including arid areas, such as Iran (*Zarrin* and *Dadashi-Roudbari*, 2022; *Darand* and *Pazhoh*, 2022; *Nazaripour* and *Mansouri Daneshvar*, 2014; *Jian-Qi*, 2012). Rainfall extremes are likely to have profound impacts on human societies (e.g., *Miri et al.*, 2023) and can lead to the loss of lives and property (*Sharifi* and *Bokaie,* 2019). In addition, simulation studies have predicted the occurrence of more extreme rainfall events due to the cumulative effects of greenhouse gases (*Zarrin et al.*, 2022; *Ayugi et al.*, 2021; *Chen et al.*, 2020; *Darand*, 2020; *Almazroui* and *Saeed*, 2020). Thus, in the past decades, there has been increased research focusing on extreme climate events to more deeply and comprehensively understand their variability (*Nourani* and *Najafi*, 2022; *Rousta et al.*, 2016). However, the studies of heavy precipitation in Iran it has not yet been perfected.

The mean annual precipitation of Iran in more than half of the surface area (60%) is less than 200 mm, and some parts (30%) get less than 50 mm annually. On this basis, Iran is located in a dry climatic zone with a mean rainfall of approximately 250 mm/year. The northern slopes of the Alborz Mountain range in the north, Zagros highlands, and northwestern Iran receive more rainfall; while the interior parts of the country receive much less precipitation (*Fig. 1*). During the last decades, some aspects of precipitation in Iran have undergone several changes, and about half of the country's surface area has been subject to them. Studies have shown that precipitation amounts during wet days as well as a number of heavy and very heavy precipitation days tend to decrease across the study area (*Alavinia* and *Zarei*, 2021). In addition, a general downward trend in annual precipitation can be observed, particularly in areas of northern, western, and northwestern Iran (*Najafi* and *Moazami*, 2016). The frequency of heavy precipitation has declined in the northwest, western and northeastern parts of Iran (*Mahbod* and *Rafiee*, 2021). While the trend of the most extreme precipitation indicators in Iran is increasing (*Balling et al.*, 2016), the relative occurrence of one-day precipitations in creating total rainfall and the frequency of rainy days on an annual scale has decreased by about 20% over the area of Iran (*Nazaripour* and *Mansouri Daneshvar*, 2014). Studies have shown an upward trend in both intensity and number of extremes, e.g., maximum daily precipitation and number of days with precipitation above the 90th percentile, across Iran (*Fathian et al.*, 2020). In general, winter (between December and March) represents the main rainy season in Iran. Most parts receive more than half of the annual precipitation totals during winter (*Domroes et al.*, 1998). Today, the research results show a change in the precipitation regime, a decrease in rainy days and total precipitation, and an increase in the concentration of precipitation in Iran (*Darand* and *Pazhoh*, 2022).

Heavy rainfall is one of the most important types of extreme weather events. Each year, Iran experiences massive heavy rainfall events, for example, the unprecedented heavy precipitation events in the western district of Iran between March 20 and April 21 in 2019 (*Fazel-Rastgar*, 2020; *Alborzi et al.*, 2022), and in the western and southwestern part of Iran in April 2016 (*Dizaji et al.*, 2019). These extreme events resulted in a great damage of life and property throughout a great number of regions. In each part of Iran, the extreme rainfalls share a portion of total rainfall amounts. The mentioned variability can be considered as climate change signals in respect of heavy rainfall events. The results of previous studies have shown variations in two important aspects of heavy rainfall events (frequency and intensity) in Iran. But in reality, the variation in frequency or intensity does not determine the share of heavy precipitation in total precipitation. The spatial distribution of the share of heavy precipitation of the total rainfall in Iran is still not clear, although a number of studies have investigated the variation of its frequency and intensity. Thus, in this study, we attempt to investigate the variation of the contribution of extreme rainfall to the total rainfall.

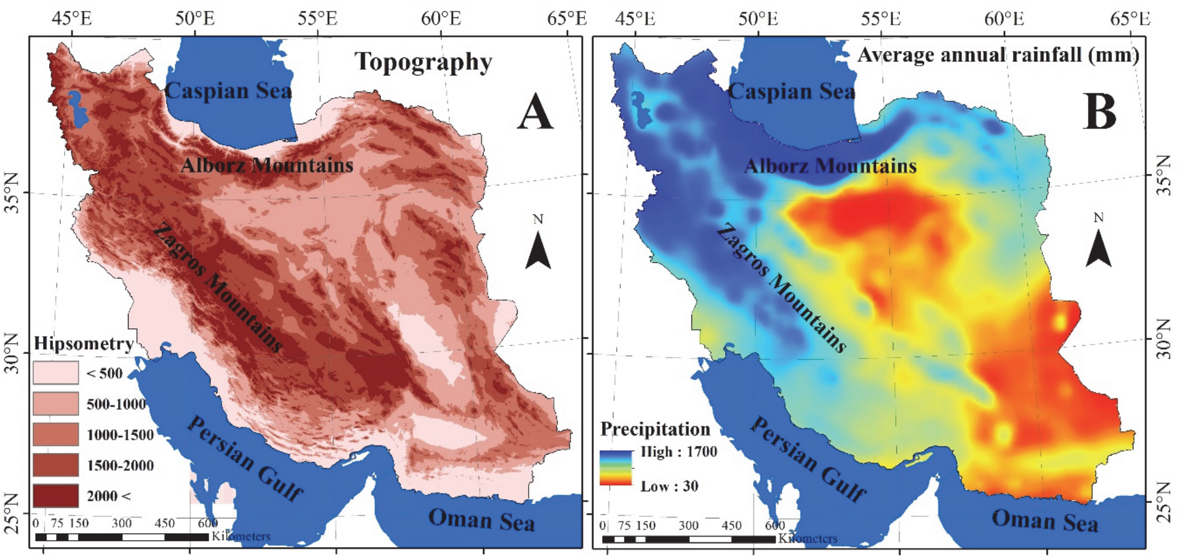

Fig. 1. Geographical distribution of topography (A) and annual long-term mean precipitation (1961–2010) (B) over Iran.

2. Data and methodology

The global estimated daily rainfall data were extracted from two high-resolution (0.25°×0.25°) databases (CHIRPS and APHRODITE) for a similar domain 43.125° to 64.125° E and 24.125° to 40.125° N. Precipitation data of the APHRODITE and CHIRPS datasets are accessible for everyone in the links https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_daily and http://aphrodite.st.hirosaki-u.ac.jp/product/APHRO_V1101/APHRO_ME/025deg_nc. Then, the two databases are merged to obtain a long-term time period. Daily rainfall data is accessible for the period 1951–2007 and 1981–2022 in APHRODITE and CHIRPS, respectively. Thus, in this study, the period of 1961–2010 is considered. Consequently, the rainfall data from 4893 points were used in this study. The threshold of heavy precipitation is estimated according to the percentile. First, we set the convention criterion ($R \geq$1mm) for the wet day, where R is the daily precipitation amount, and then, we modified the combined precipitation database accordingly. Subsequently, we calculated the 95th and 90th percentiles of daily rainfall for the wet days of each year from 1961–2010. Then, the 30-year mean of the 95th and 90th percentile values are regarded as the heavy precipitation threshold. Here, a heavy precipitation day is considered a day with rain more than the extreme precipitation threshold. The heavy precipitation for one year is considered the sum of precipitation for the heavy precipitation days of the year, and the total precipitation is considered the sum of precipitation for all rainy days of the year. The share of heavy precipitation to the total rainfall is calculated as

$$CRNN_j = \frac{\sum_{w=1}^{W} R_{wj} \quad whrer\ R_{wj} > R_{wj}NN}{R_j} \ , \tag{1}$$

where $CRNN_j$ is the percentage of total rainfall contributed by heavy rainfall in any year, R_j is the total amount of daily rainfall on wet days ($R \geq$1mm) in period j, R_{wj} is the sum of daily precipitation on heavy precipitation days ($R >$ 90th and 95th percentile) and represents the count of wet days in the period j. The output of applying this equation to the merged database creates two new databases of the share of heavy precipitations to total rainfall, which are named CR^{90} and CR^{95}, respectively. In this database, the share of heavy precipitation to total rainfall in every year (up to 50 years) is available at every point (up to 4893 points).

Trend analysis can be performed by parametric and nonparametric tests. Nonparametric techniques are more suitable for time series when statistical distributions are not fit for them. The negligible influence of this method on extreme values is one of the benefits of this method (*Alavinia* and *Zarei*, 2021). Considering these advantages, this research used the Mann-Kendall test to determine the trend in the share of heavy precipitation to total rainfall. The null (H_0) and alternative (H_a) hypotheses of the MK nonparametric test are defined as the non-existence and existence of a trend in time series (*Shadmani et al*., 2012). Negative and positive MK values indicate a decreasing or increasing trend, respectively (*Nazaripour* and *Mansouri Daneshvar*, 2014). The Mann-Kendall statistic S is given as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) . \tag{2}$$

The application of the trend test is done to the time series x_i (i=1, 2, …, n-1) and x_j (j=i+1, 2, …., n). each of the data point x_i is taken as a reference point which is evaluated with the other of the data points x_j, and the value $sgn(x_j - x_i)$ is computed as

$$sgn\left(x_j - x_i\right) = \begin{Bmatrix} +1 & if & \left(X_j - X_i\right) > 0 \\ 0 & if & \left(X_j - X_i\right) = 0 \\ -1 & if & \left(X_j - X_i\right) < 0 \end{Bmatrix} . \tag{3}$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. Where n is the number of observed series, X_j and X_i are data values at time j and i, respectively. The Mann-Kendall statistic S is standardized as follows

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S > 0, \\ 0 & if \quad S = 0, \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S < 0. \end{cases} \tag{4}$$

The variance statistic is given as

$$\mathrm{Var}\ (S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)\right] , \tag{5}$$

where t_i is considered as the number of ties up to sample i, m represents the number of series in which at least one duplicate data exists. A positive (negative) value of Z_{MK} signifies an increasing (decreasing) trend of the time series. A significance level α is also utilized for testing either an increasing or a decreasing trend (two-tailed test). If Z_{MK} is greater than $Z_{\alpha/2}$, where α depicts the significance level, then it is recognized that the trend is significant. The magnitude of the trend was predicted by the Sen's estimator (*Sen*, 1968). Here, the slope (T_i) of all data paired is computed as

$$T_i = \frac{(x_j - x_k)}{(j-k)} \qquad for\ \ i = 1, 2, \ldots, N\ , \tag{6}$$

where x_j and x_k are considered as data values at time j and $k (j > k)$ correspondingly. The median of these N values of T_i is represented by Sen's estimator of the slope, which is given as

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N\ is\ odd, \\ \frac{1}{2}\left\{T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right\} & N\ is\ even\ . \end{cases} \tag{7}$$

The Sen's estimator is computed as $Q_{med} = T(N+1)/2$ if N is odd, and it is considered as $Q_{med} = [T(N/2) + T_{(N+2)/2}]$ if N is even. In the end, Q_{med} is computed by a two-sided test at the $100(1-\alpha)\%$ confidence level. The positive (negative) value of Q_i indicates an increasing (decreasing) trend in the time series.

3. Results and discussion

The mean annual precipitation of Iran in more than 70% of area is below 250 mm, some parts get less than 50 mm, and only less than 5% of the surface area of Iran receives above 500 mm annually. The annual mean rainfall ranges from smaller than 50 mm up to beyond 1500 mm (*Fig. 1*). On this basis, Iran is located in an arid and semiarid zone. The topography is also associated with much of the spatial variation of annual precipitation. The precipitation pattern in Iran is heavily affected by the Alborz and Zagros mountain ranges. The wettest areas are located in northern Iran, on the southwestern coast of the Caspian Sea, and on the western and southern slopes of the Zagros Mountains. The interior areas receive much less precipitation .These regions (i.e., the Lut and Kavir deserts) are referred to as arid areas (*Alijani et al.*, 2008).

Fig. 2 shows the percentage ratio of rainfall caused by extreme daily rainfall events (R > 95th percentile) to the total rainfall over Iran. To better understand the changes, the share of heavy rainfalls in two different 30-year periods (1961–1990 and 1991–2020) have been investigated. Heavy daily rainfall events contributed a large proportion (almost 50%) of the total precipitation over Iran during the periods examined (*Fig. 2*). The results in the first period (1961–1990) imply that heavy daily rainfall events contributed 20% of the total annual precipitation in the wettest zones. In the second period (1991–2020), this contribution has increased by about 5%. By evaluation, the share of heavy rainfall events to the total rainfall in arid areas is more than twice that of wet areas.

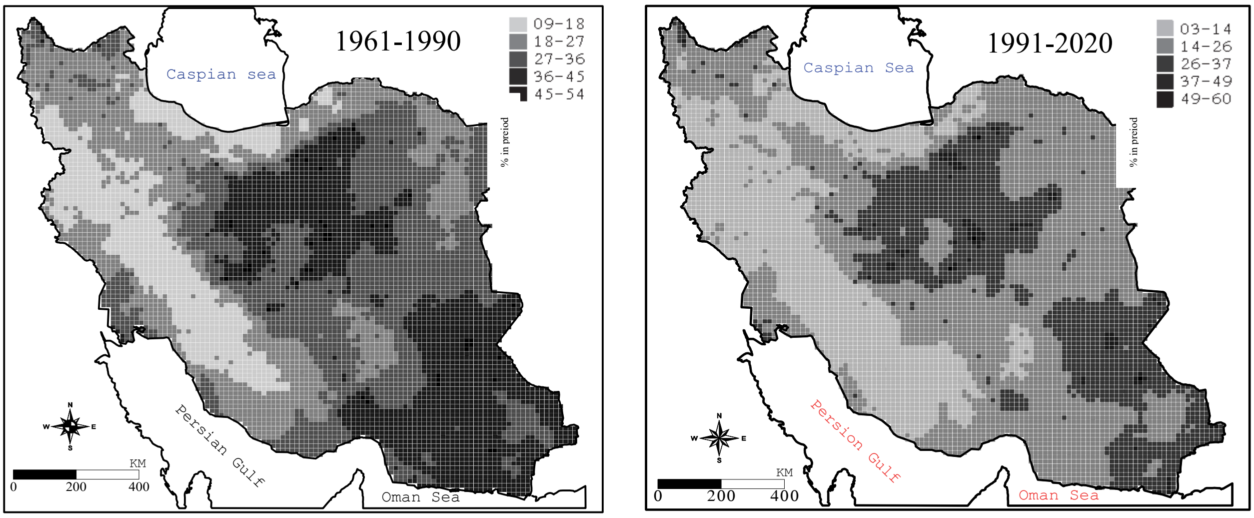

Fig. 2. Relative share of heavy daily rainfall events (R > 95th percentile) to the total rainfall over Iran during the periods 1961–1990 (left) and 1991–2020 (right).

Trend analysis of the share of heavy daily rainfall events to total precipitation has been done in the present research for 50 years (1961–2010). Mann-Kendall test and Sen's slope estimator have been used for the recognition of the trend. The spatial distribution of significant trends (at the 5% confidence level) and also the magnitude of the decadal trend for the share of extreme rainfall to total rainfall in Iran are shown in *Figs. 3* and *4*. The results of the trend analysis using the Mann-Kendall test indicate the existence of a significant upward trend in the share of heavy rainfall to total precipitation in the long period of 1961–2010 in the entire area of Iran. These results are in line with earlier studies (such as *Zarin* and *Dadashi-Roudbari*, 2022; *Almazroui* and *Saeed*, 2020). The integrity of the upward trend is stretched in a wide strip from the southwest to the northeast of Iran. These areas correspond to the Zagros mountain range, especially its wide parts on the shores of the Persian Gulf, and also to the central deserts. This increasing trend is evident in the country of Iraq and can be extended to the Arabian Peninsula as well (*Almazroui* and *Saeed,* 2020). These results seem reasonable because, on the one hand, due to global warming, the moisture content of the atmosphere (water vapor) in the surrounding areas of water beds has increased, leading to heavy rains. On the other hand, wet days are decreasing in desert areas and far from moisture sources, and it leads to intensifying the concentration of precipitation and increasing its intensity. The magnitude of the decadal trends of the contribution of heavy precipitation to total rainfall in southwestern Iran is higher than in the central deserts. In the southwestern regions, the share of heavy rain is increasing up to 5%, while in the central deserts, it is up to 1%.

The southwestern regions of Iran is the the drainage basin of the major and permanent rivers (e.g., Karun, Karkheh, Jarahi, etc.) that originate from the heights of Zagros and lead to the Persian Gulf. Floods as natural hazard have always threatened the human and natural environments of these regions. In recent decades, the natural environment of these areas has become extremely vulnerable as a result of natural climate change (drought) and anthropogenic activities (dam construction, forest destruction, agriculture, etc.). As a result of these conditions, flooding is expected to occur more frequently and more severely in these areas in the future.

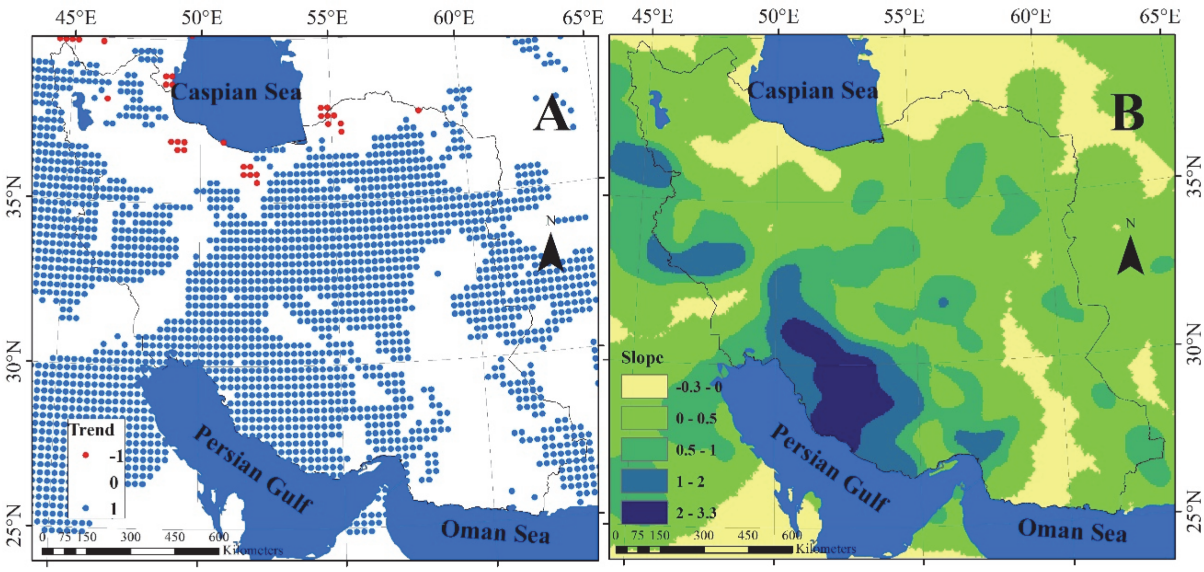

Fig. 3. Spatial distribution of significant trends (left) and magnitude of trends (right) in CR95 based on Mann-Kendall and Sen's estimator tests in the 1961–2010 period, respectively. Filled blue(red) circles indicate positive (negative) trends at the 5% significance level.

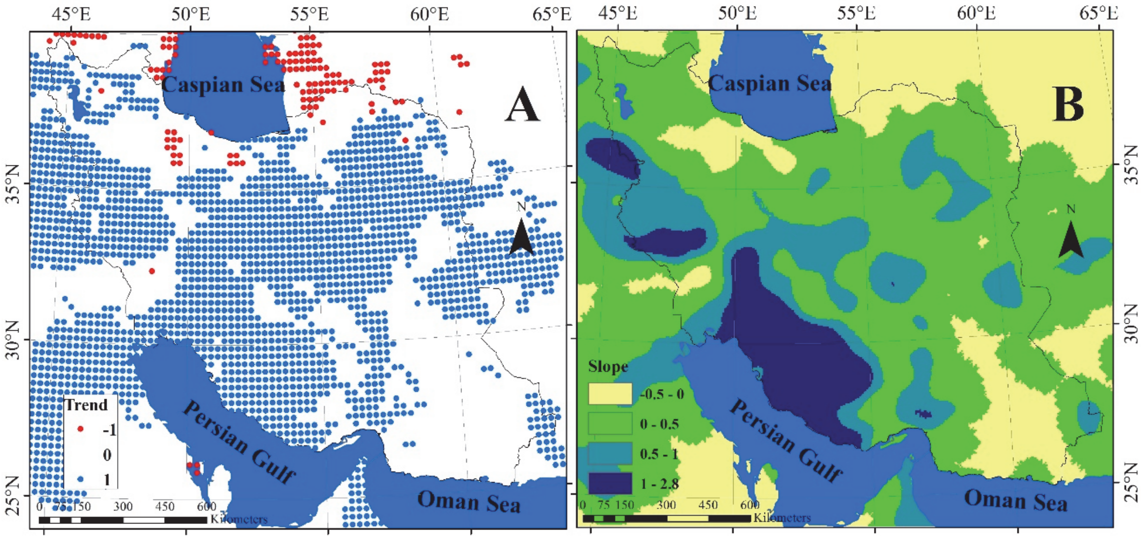

Fig. 4. Spatial distribution of significant trends (left) and (right) in CR90 based on Mann-Kendall and Sen's estimator tests in the 1961–2010 period, respectively. Filled blue(red) circles indicate positive (negative) trends at the 5% significance level.

4. Conclusion

As a general result, the change in the relative share of heavy rainfall to the total precipitation in Iran is statistical evidence of the change in Iran's rainfall regime. This means that the precipitation regime will become more concentrated and intense. The analysis of the contribution of heavy rainfall to total precipitation in the territory of Iran based on the data of APHRODITE and CHIRPS databases in the last half century (1961–2010) indicates the existence of a strong positive (upward) and reliable trend. The spatial distribution of increasing trends in a wide strip has a southwest-northeast arrangement. The relative share of heavy daily rainfall events to total precipitation has increased over the southwestern and central parts of Iran from the past to the current climate. The amount of increase in the share of heavy rainfall to the total precipitation is more prominent in the middle parts of the Zagros Mountains. The amount of decennial increase in the share of extreme rainfall to total precipitation also decreases from southwest to northeast. The increasing trend of this indicator in the territory of Iran is an evidence of the change in Iran's rainfall regime. This means that the increase in the share of heavy rainfall to the total rainfall has led to a decrease in the frequency of rainy days (wet days) and to an intensification in the intensity and concentration of precipitation in Iran.

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References

Alavinia, S. H., and *Zarei, M. 2021*. Analysis of spatial changes of extreme precipitation and temperature in Iran over a 50-year period. *Int. J. Climatol. 41*, E2269-E2289. https://doi.org/10.1002/joc.6845

Alborzi, A., Zhao, Y., Nazemi, A., Mirchi, A., Mallakpour, I., Moftakhari, H., ... and *AghaKouchak, A*. 2022. The tale of three floods: From extreme events and cascades of highs to anthropogenic floods. *Weather Climate Ext. 38*, 100495. https://doi.org/10.1016/j.wace.2022.100495

Alijani, B., O'Brien, J., and *Yarnal, B*. 2008. Spatial analysis of precipitation intensity and concentration in Iran. *Theor. Appl. Climatol. 94*(1), 107–124. https://doi.org/10.1007/s00704-007-0344-y

Almazroui, M., and *Saeed, S*. 2020. Contribution of extreme daily precipitation to total rainfall over the Arabian Peninsula. *Atmos. Res. 231*, 104672. https://doi.org/10.1016/j.atmosres.2019.104672

Ayugi, B., Zhihong, J., Zhu, H., Ngoma, H., Babaousmail, H., Rizwan, K., and *Dike, V*. 2021. Comparison of CMIP6 and CMIP5 models in simulating mean and extreme precipitation over East Africa. *Int. J. Climatol 41*, 6474–6496. https://doi.org/10.1002/joc.7207

Balling, R. C., Keikhosravi Kiany, M. S., Sen Roy, S., and *Khoshhal, J*. 2016. Trends in extreme precipitation indices in Iran: 1951–2007. *Adv. Meteorol 2016*. ID 2456809. https://doi.org/10.1155/2016/2456809

Chen, H., Sun, J., Lin, W., and *Xu, H*. 2020. Comparison of CMIP6 and CMIP5 models in simulating climate extremes. *Sci. Bull. 65*, 1415–1418.https://doi.org/10.1016/j.scib.2020.05.015

Darand, M. 2020. Projected changes in extreme precipitation events over Iran in the 21st century based on CMIP5 models. *Climate Res. 82*, 75–95.https://doi.org/10.3354/cr01625

Darand, M., and *Pazhoh, F*. 2022. Spatiotemporal changes in precipitation concentration over Iran during 1962–2019. *Climatic Change*, *173*(3), 1–22.https://doi.org/10.1007/s10584-022-03421-z

Dizaji, R. A., Ardalan, A., and *Fatemi, F*. 2019. Response functions in disasters: Iran flash flood 2016. *Dis. Medicine Public Health Prepar. 13*, 842–844. https://doi.org/10.1017/dmp.2018.94

Domroes, M., Kaviani, M., and *Schaefer, D:* 1998. An analysis of regional and intra-annual precipitation variability over Iran using multivariate statistical methods. *Theor. Appl. Climatol. 61*, 151-159.

Easterling, D. R., Evans, J. L., Groisman, P. Y., Karl, T. R., Kunkel, K. E., and *Ambenje, P*. 2000. Observed variability and trends in extreme climate events: a brief review. *Bull. Amer. Meteorol. Soc. 81*(3), 417–426.https://doi.org/10.1175/1520-0477(2000)081<0417:OVATIE>2.3.CO;2

Fathian, F., Ghadami, M., Haghighi, P., Amini, M., Naderi, S., and *Ghaedi, Z*. 2020. Assessment of changes in climate extremes of temperature and precipitation over Iran. *Theor. Appl. Climatol. 141*(3), 1119–1133. https://doi.org/10.1007/s00704-020-03269-2

Fazel-Rastgar, F. 2020. Extreme weather events related to climate change: widespread flooding in Iran, March–April 2019. *SN Appl. Sci. 2*(12), 1–14.https://doi.org/10.1007/s42452-020-03964-9

Jian-Qi, S. 2012. The contribution of extreme precipitation to the total precipitation in China. *Atmos. Oceanic Sci. Lett. 5*(6), 499–503.https://doi.org/10.1080/16742834.2012.11447046

Karimi, S., Nazaripour, H., and *Hamidianpour, M*. 2021. Spatial and temporal variability of precipitation extreme indices in arid and semi-arid regions of Iran for the last half-century. *Időjárás 125*, 83–104.https://doi.org/10.28974/idojaras.2021.1.4

Kunkel, K.E., Pielke, R.A., and *Changnon, S. A*. 1999. Temporal fluctuations in weather and climate extremes that cause economic and human health impacts: A review. *Bull. Amer Meteorol Soc 80*(6), 1077–1098.https://doi.org/10.1175/1520-0477(1999)080<1077:TFIWAC>2.0.CO;2

Mahbod, M., and *Rafiee, M. R*. 2021. Trend analysis of extreme precipitation events across Iran using percentile indices. *Int. J. Climatol.41*, 952–969.https://doi.org/10.1002/joc.6708

Miri, M., Raziei, T., Zand, M., and *Kousari, M. R*. 2023. Synoptic aspects of two flash flood-inducing heavy rainfalls in southern Iran during 2019–2020. *Nat. Hazards 115*, 2655–2672. https://doi.org/10.1007/s11069-022-05658-4

Najafi, M. R., and *Moazami, S*. 2016. Trends in total precipitation and magnitude–frequency of extreme precipitation in Iran, 1969–2009. *Int. J. Climatol 36*, 1863–1872. https://doi.org/10.1002/joc.4465

Nazaripour, H., and *Mansouri Daneshvar, M. R*. 2014. Spatial contribution of one-day precipitations variability to rainy days and rainfall amounts in Iran. *Int. J. Environ. Sci. Technol. 11*, 1751–1758. https://doi.org/10.1007/s13762-014-0616-x

Nourani, V., and *Najafi, H*., 2022: Historical changes in hydroclimatic extreme events over Iran. In Climate Impacts on Extreme Weather Elsevier. 101–115. https://doi.org/10.1016/B978-0-323-88456-3.00001-0

Rousta, I., Soltani, M., Zhou, W., and *Cheung, H.H*. 2016: Analysis of extreme precipitation events over central plateau of Iran. *Amer. J. Climate Change 5*, 297–313. https://doi.org/10.4236/ajcc.2016.53024

Sen, P. K. 1968. Estimates of the regression coefficient based on Kendall's tau. *J. Amer. Stat. Assoc. 63*, 1379–1389. https://doi.org/10.1080/01621459.1968.10480934

Shadmani, M., Marofi, S., and *Roknian, M*. 2012. Trend analysis in reference evapotranspiration using Mann-Kendall and Spearman's Rho tests in arid regions of Iran. *Water Resour. Manage. 26*, 211–224. https://doi.org/10.1007/s11269-011-9913-z

Sharifi, L., and *Bokaie, S.* 2019. Priorities in prevention and control of flood hazards in Iran 2019 massive flood. *Iranian J. Microbiol.* 11(2), 80–84.

Zarrin, A., and *Dadashi-Roudbari, A*. 2022. Spatiotemporal Variability, Trend, and Change-Point of Precipitation Extremes and Their Contribution to the Total Precipitation in Iran. *Pure and Appl. Geophys. 179*, 2923–2944. https://doi.org/10.1007/s00024-022-03098-6

Zarrin, A., Dadashi-Roudbari, A., and *Hassani, S*. 2022. Future changes in precipitation extremes over Iran: Insight from a CMIP6 bias-corrected multi-model ensemble. *Pure Appl. Geophys.* 179, 441–464. https://doi.org/10.1007/s00024-021-02904-x