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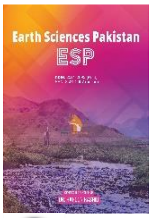

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*RESEARCH ARTICLE*

# RAINFALL TRENDS ANALYSIS IN CONTEXT OF CLIMATE CHANGE IN SAUDI ARABIA : A CASE STUDY OF HA'IL REGION

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**ABSTRACT**

This study used the rainfall dataset collected for 1978-2015 in 8 rain stations located in Ha'il region. The purpose of this study is to analyze the variations and trends of rainfall events through a statistical analysis of data recorded. The analyze the rainfall variability has been processed using the coefficient of variation (CV) and Standardized Analyze Index (SAI) and plotted. While the rainfall trends have been analyzed by three statistically methods widely used: Simple Moving-Average (SMA), Homogeneity of variance (Hartley's Fmax-ratio) and Semi-averages. The trends analysis of annual rainfall shows that the fluctuations or variations in climatic parameters is a recurring phenomena in the studied stations. Inter-annual variability of rainfall and the cumulative frequency of rainy days are characterized by the high coefficients of variation. In addition, the values of Chi square test reveals the significant Standardized Anomaly Index (SAI) of rainfall. Accordingly, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). These results indicate that the warming climate of Ha'il region is accelerating in recent decades, which may have severe socioeconomic repercussions in many sectors especially the agriculture and surface water resources.

**KEYWORDS**

Variations of rainfall, precipitation, global warming, Gumbel law, return periods.

## 1. INTRODUCTION

Now, the water resource has the prime concern for any future planning and development including flood control, flood protection and sustainable water resources management in Saudi Arabia. The rainfall available is an important factor for determining the availability of water to full file the different demand mainly for agriculture, domestic demand, groundwater, etc. Global climate changes affect the long-term rainfall pattern causes availability of water and may danger of occurrence of serious drought and flood. Global warming affects the rainfall change which influence the stream flow rate, hydrologic cycle, water demand requires review in planning, design and management of hydraulic structures (Nalley, 2012). Changes in run-off and its distribution will depend on likely future climate scenarios. The trend analysis of rainfall, temperature and other climatic variables on different spatial scales will help in understanding the future climate scenarios (Ganguly et al., 2015). Since rainfall and temperatures trends will have significant impact on climate change (Rutkowska, 2013). Consequently, any rise or fall in rainfall has several consequent implications in water resources development projects (Serrano et al,1998).

In the same concept, this study has been attempted to investigate the trend of climatic variables for Ha'il area in Northern central part of Saudi Arabia. There are two main variables which are critical in studies of climatic change: rainfall and temperature were summarized in this study. So, changes in temperature will impact directly the various hydrological and climatic processes such as rainfall pattern and their sequences (Basistha, et al., 2008).

The trend analysis of temperature and rainfall time series includes determination of increasing and decreasing trend and magnitude of trend and its statistical significance by using parametric and non-parametric statistical methods (Jain and Kumar, 2012). Trend analysis in various study shows that there are generally Hartley's F-max, Moving averages, Semi-averages and Straight linear regression methods were used and preferred by various researchers (Machiwal and Jha, 2008 ; Dong, et al., 2020). The main goal of this study is to analyze the rainfall and temperature trends as indicators of climate change in Ha'il region, using four rain indicators (Annual rain, Daily maximum rain, Actual average of daily rain, Number of rainy days) and four temperatures indicators (Mean temperature, Mean of maximum temperatures, Maximum of daily temperature and Minimum temperatures).

Scientific knowledge and literature relating to the climate and climate change in Saudi Arabia is scattered, incomplete and limited (Hasanean and Almazroui, 2015). The analysis of daily total rainfall recorded from a meteorological data collection station in Dhahran, Saudi Arabia over a period of 37 years spanning from 1970 to 2006 indicated a warming trend of the local air and the total annual rainfall values showed almost a constant trend during the reporting period (Rehman, 2010). The climatic datasets from 27 ground observations for the period 1978-2009, showed a significant decreasing trend (47.8 mm per decade) of the observed annual rainfall in the last half of the analysis period, with a relatively large inter-annual variability.

The detailed features of dry and wet spell durations and rainfall intensity series available (1971-2012) on daily basis for the Jeddah area (Western Saudi Arabia), show trend changes in annual and seasonal analyses confirm that the rainy seasons are tending to have more intense rainfall while the seasons are becoming drier (Subyani and Hajjar, 2016). The future trends of rainfall assessed for several regions in Saudi Arabia showed the increase and variable pattern of rainfall may increase uncertainty in developing sustainable water resource management strategies (Tarawneh and Chowdhury, 2018).

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## 2. Materials And Methods

### 2.1 Study area and Data used

The study area covered a geographical area of about 120000 km2, occupying 5% of the Saudi Arabia area. The study area extends from 25o30' to 29o 15' North latitudes and 39o30' to 44o15' East longitudes in the middle part of the Northern Saudi Arabia. It is bordered to the North by the regions of Al-Jawf and the Northern borders, to the East by Al Qasim region and the Eastern Province, to the South by Al Madinah Al Munawwarah region, and to the West by Tabuk region (Fig.1). Consequently, Ha'il area, is classified under a hot desert climate (BWh) of the Köppen-Geiger climate classification, with hot summers and cool winters. It has a somewhat milder climate than other Saudi cities due to its higher altitude.

Geologically, Ha'il province is divided into two main parts: Arabian shield in the west, and the Arabian shelf in the east. The Arabian shield consists of igneous and metamorphic rocks, and the Arabian shelf consists of a different group of sedimentary rocks, and different geological formations deposited in oblique sedimentary layers to East and North-East. Therefore, the thickness of the sediments increases gradually in the same direction. It has a varied relief composed mainly by three major components: Salma and Aja mountains, in the West, Ha'il plain in the middle and East; and Wadi Ad Dayri', which cross the region, from the South west to the North East. In general, Ha'il region is dominated by two air masses, namely, the Polar Continental that occurs from December to February and Tropical Continental that occurs in summer from June to September. Both systems are affected by minor incursions of Polar Maritime and Tropical Maritime air (Fisher and Membery, 1998).

All of the climatic conditions, soil properties and relief topography are clearly contributed to the presence of abundant plant diversity in Hail region. So, the mountainous of Salma and Aja are famous for the widespread of (Dianthus cyri). While the (Haloxylon salicornicum), Calligonum comosum), (Ephedra alata) and (Panicum turgidum) are the main plants of the sand dunes environment. However, (Suaeda) is the most widespread plant clans in the Sabkhas environment.

In the plains environment, two major plants clans, namely (Rhanterium epapposum) and (Haloxylon salicornicum) are widely spread. The water courses are also an important environment for a number of plants mainly (Lycium shawii) and (Acacia gerrardii). In addition, the main agricultural activity of Ha'il province is the date production and vegetable cultivation. These two sectors is undergoing considerable development as it is the fundamental resource of several farmers. At the same time, these activities include camels breeding and livestock.

Datasets of rainfall and temperature were obtained from 8 rain stations and the meteorological station of Ha'il airport for the period of 1978-2015 (Table 1 and Figure 1).

**Table 1:** Geographic coordinates of studied rain stations.

| Station | Latitude (N) | Longitude (E) | Height (m) | Code | Station No. | Data collection years | Data collection period |
|---|---|---|---|---|---|---|---|
| Ha'il | 27°15' | 41°34' | 990 | 101 H | 191 | 1978-2015 | 38 |
| Baq'aa | 27°52' | 42°23' | 755 | 103 H | 193 | 1978-2015 | 38 |
| Jubbah | 28°01' | 40°56' | 920 | 106 H | 196 | 1978-2015 | 38 |
| Faydat ibn Suwaylim | 27°04' | 40°25' | 910 | 108 H | 198 | 1978-2015 | 38 |
| Simirah | 26°29' | 42°07' | 950 | 105 H | 793 | 1978-2015 | 38 |
| Al Ha'it | 25°59' | 40°27' | 1064 | 111 H | 797 | 1978-2015 | 38 |
| Al Uqlat | 27°06' | 41°17' | 1215 | 208 H | 508 | 1978-2015 | 38 |
| Al Ghazalah | 26°47' | 41°21' | 980 | 215 H | 812 | 1978-2015 | 38 |
| Ha'il meteorology | 27°26' | 41°42' | 1001.5 | 40394 | | 1978-2015 | 38 |

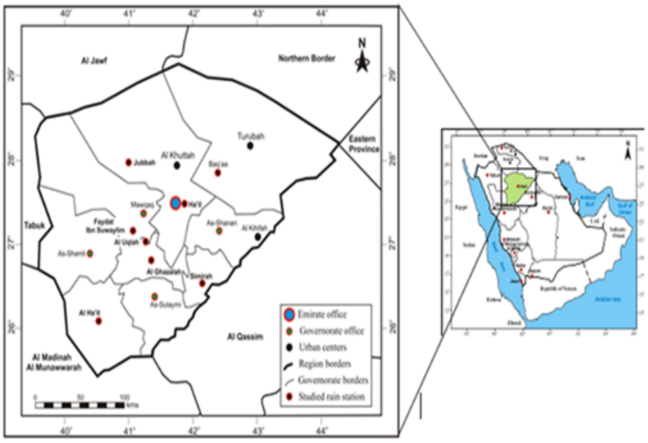



**Figure 1:** Geographic location of selected stations.

### 2.1 Rainfall variability

#### 2.1.1 Coefficient of variation (CV)

The coefficient of variation (CV) determines the variability of the rainfall or temperature in specific region. A high value of (CV) indicates that the rainfall or temperature variability is greater, where a lower value means the opposite. The (CV) is computed by the following equation:

$$CV = \frac{\sigma}{\mu}$$

Where ($\sigma$) is the standard deviation and ($\mu$) is the mean of chosen temporal scale. (CV) is used to classify the degree of variability events into three categories : (Asfaw et al., 2018).

- Low CV (less than 20%)
- Moderate CV (from 20% to 30%).
- High CV (Above 30%).

The statistics descriptive of the recorded annual rainfall and rainy days are summarized in the table 2 and 3, respectively.

#### 2.2.2 Standardized Anomaly Index (SAI)

The Standardized Anomaly Index (SAI) was introduced by E.B. Kraus in the mid-1970s and was examined closely by Katz and Glantz at the National Center for Atmospheric Research, United States, in the early 1980s. SAI was developed for identifying drought events, especially in areas frequented by drought. The SAI can be computed by applying the follow equation:

$$SAI = \frac{X_i - X'}{Sd}$$

Where, ($X_i$) is the annual rainfall of the particular year, (X') is the long-term mean annual rainfall over a period of observation and (Sd) is the standard deviation of annual rainfall over that period of observation. So, positive value suggest a time of wet situation relative to the period of reference chosen, while the negative value ones imply a drought condition (Table 5).

### 2.3 Rainfall trend analysis

#### 2.3.1 Simple Moving Averages (SMA) method

The formula for Simple Moving Average is written as follows:

$$SMA = (A_1 + A_2 + \ldots\ldots\ldots A_n) / n$$

Where A is the average in period n; and **n** is the number of periods.

#### 2.3.2 Homogeneity of variance test

A homogeneity of variances test which is based on a $F_{max}$ statistic used the ratio of the largest variance to the smallest variance (Hartley, 1950). The exact distribution of Hartley's F-max statistic is known under homogeneity of variances with equal sample sizes and Hartley has given a table of the upper 5 % points of this statistic. (David, 1952) gave corrections to this table.

This is one of the most popular statistics for comparing the semi averages. In this paper, Hartley's $F_{max}$ statistic for testing the homogeneity of variances used the equal sample sizes for 19 years; with the first part (1978-1996) and the second part (1997-2015) of the time-series. Hartley's $F_{max}$ statis tic is not robust when the underlying distribution is not normal or unequal sample sizes (Conover et al., 1981 ; Rivest, 1986). However, the reasons for using $F_{max}$ statistic are as follows. Firstly, the rain and temperature data recorded during a continuous and common time series (38 years) available at every studied station. Secondly, the rainfall and temperature data is in general, normally distributed. Thirdly, Hartley's statistic is still easy to compute using an equal sample sizes (Gupta, 1987 ; Chu and Sutradhar, 1995). Fourthly, also with the increase of usage and availability of several computer software, it is easier to apply $F_{max}$ ratio with a high accuracy.

To apply $F_{max}$ method, the time-series were divided into two equal parts with respect to time. However, the dataset is homogeneous if the computed $F_{max}$ value is smaller than the critical $F_{max}$ value at the level 0.05 and degree of freedom [k and n].

#### *2.3.3 Semi-averages method*

To apply the semi-averages method, the time-series were divided into two equal parts with respect to time. And then we compute the arithmetic mean of the two parts. The trend values can then be read from the ratio between the semi-averages of the first and the second parts ($X_1'$, $X_2'$) of every period ($T_1$, $T_2$). So, the ratio value greater than 1 indicates the increasing trend and the ratio value less than 1 represents the decreasing trend. However, the trend is significant at the level 0.05 and degree of freedom [d.f = ($n_1$+$n_2$) – 2], if : (Gregory, 1970 ; Oliver, 1981).

- The computed T-student value is greater the critical T value.
- The absolute difference I$X'_1$- $X'_2$I > 2 SE or 3 SE, at the same level 0.05 and degree of freedom.

The trend indicator "b" was defined as the ratio of the difference between the semi-averages and the difference between the middle of the two parts, expressed as follows:

$$b = \frac{X'_2 - X'_1}{T_2 - T_1}$$

Where, $X'_1$ and $X'_2$ are the semi-averages of the first and the second parts ($T_1$ , $T_2$) the middle of every part. The estimated straight trend line passes through the two points ($X'_1$, $X_2'$).

The level significance of trend can be determined by comparison between the difference of the semi-averages ($X'_2$ – $X'_1$) and the standard error (SE), expressed as follows:

$$S.E\left|X'_1 - X'_2\right| = \left[\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right]^{0.5}$$

Where, ($\sigma_1^2$ , $n_1$) are the variance and the number of time units (years) covered by the first part; ($\sigma_2^2$ , $n_2$) are the variance and the number of time units (years) covered by the second part. So, the T-student test can be computed using the following equation:

$$t = \frac{\left|X'_1 - X'_2\right|}{\left[\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right]^{0.5}}$$

**Table 2:** Descriptive statistics of annual rainfall at the studied stations

| Year | Simirah | Al Ha't | Faydat | Al Ghazalah | Ha'il, | Al Uqlah | Baqa'a | Jubbah |
|---|---|---|---|---|---|---|---|---|
| Mean | 2.0 | 20.0 | 28.6 | 31.0 | 42.4 | 22.2 | 4.3 | 9.0 |
| Median | 131.5 | 25.8 | 15.5 | 102.2 | 63.6 | 89.6 | 2.2 | 35.6 |
| Mode | 38.6 | 31.5 | 71.0 | 67.6 | 31.1 | 75.0 | 92.8 | 19.0 |
| S D | 82.0 | 53.4 | 98.5 | 90.2 | 41.5 | 90.2 | 130.6 | 20.5 |
| Variance | 212.6 | 134.8 | 100.0 | 76.0 | 35.0 | 120.2 | 157.9 | 68.8 |
| CV | 0.86 | 0.71 | 0.60 | 0.68 | 0.59 | 0.73 | 0.80 | 0.87 |
| Skewness | 21.5 | 43.5 | 49.5 | 57.8 | 26.6 | 62.2 | 37.4 | 14.9 |
| Kurtosis | 2.0 | 58.9 | 189.0 | 142.8 | 65.7 | 202.8 | 232.6 | 36.8 |
| Range | 101.0 | 91.7 | 158.2 | 105.8 | 48.7 | 122.6 | 97.7 | 27.3 |
| Minimum | 85.5 | 105.2 | 132.5 | 141.4 | 65.0 | 177.2 | 86.4 | 36.4 |
| Maximum | 81.6 | 31.3 | 14.5 | 50.2 | 23.1 | 36.2 | 38.0 | 12.9 |

**Table 3:** Descriptive statistics of the rainy days at the studied stations

| **Year** | Simirah | Al Ha't | Faydat | Al Ghazalah | Ha'il, | Al Uqlah | Baqa'a | Jubbah |
|---|---|---|---|---|---|---|---|---|
| Mean | 11.5 | 7.3 | 6.6 | 9.8 | 12.1 | 9.9 | 9.2 | 4.2 |
| Median | 9.5 | 7.0 | 6.0 | 8.0 | 9.5 | 7.0 | 8.0 | 4.0 |
| Mode | 5.0 | 8.0 | 5.0 | 3.0 | 6.0 | 4.0 | 7.0 | 2.0 |
| S D | 8.3 | 5.6 | 3.5 | 7.2 | 8.9 | 8.3 | 5.6 | 2.4 |
| Variance | 68.4 | 31.2 | 11.9 | 52.3 | 79.3 | 69.1 | 31.2 | 5.8 |
| CV | 0.72 | 0.77 | 0.52 | 0.74 | 0.74 | 0.84 | 0.61 | 0.57 |
| Skewness | 1.0 | 2.1 | 0.9 | 0.7 | 1.2 | 1.4 | 0.8 | 0.6 |
| Kurtosis | 0.7 | 7.8 | 0.7 | -0.9 | 0.9 | 1.8 | 0.5 | -0.4 |
| Range | 34.0 | 30.0 | 14.0 | 23.0 | 36.0 | 36.0 | 23.0 | 9.0 |
| Minimum | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| Maximum | 35.0 | 31.0 | 16.0 | 24.0 | 38.0 | 37.0 | 24.0 | 10.0 |

## 3. Results And Discussion

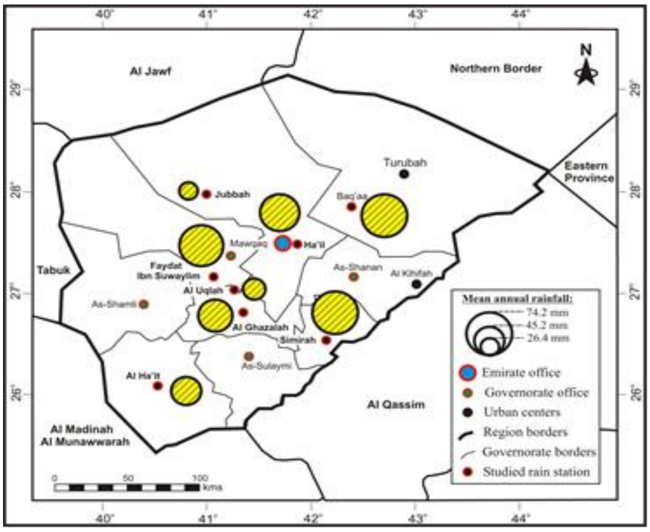
### 3.1 Annual rainfall variability

The variability of annual and daily rainfall is analyzed using two statistical parameters; coefficient of variation (CV) and standardized anomaly index (SAI).

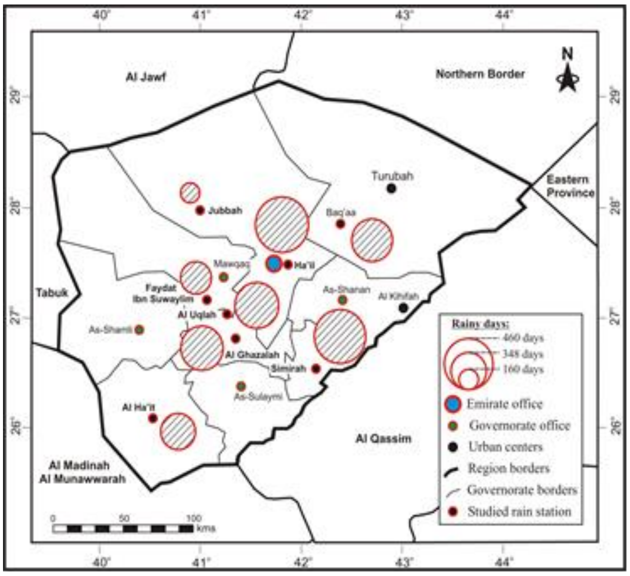
#### *3.1.1 Coefficient of variation (CV)*

The mean annual rainfall varies from 26.4 mm in Jubbah station to 74.2 mm in Simirah station. But, the annual rainfall is ranged for extremely dry years from 2.0 mm (1978) at Simirah to 12.9 mm (2007) at Faydat Ibn Suwaylim. However, it is ranging for relatively rainy years from 76.9 mm (1991) at Ha'il to 282.8 mm (1993) at Simirah. Interannual variability of rainfall is characterized by the high coefficients of variation, from 0.59 at Ha'il to 0.87 at Jubbah. So, the range of annual rainfall varies from 70.4 mm to 280.8 mm at Ha'il and Simirah, respectively (Tab. 7 and Fig. 3).

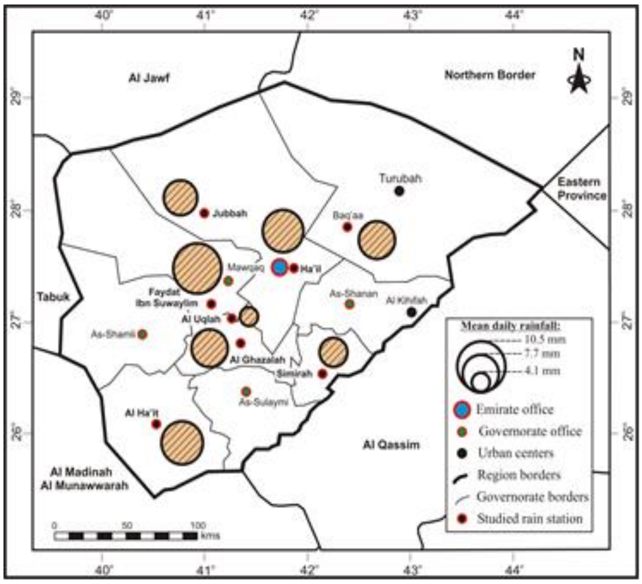
In the same context, the cumulative frequency of rainy days during the period of 1978-2015 (38 years) shows that the maximum is observed with 460 days at Ha'il and the minimum with 161 days at Jubbah (Figure 2B). Consequently, the of rainy days varies from 5 days/year at Jubbah to 13 days/year at Ha'il. But during the extremely dry years, the total of rainy days don't exceed 2 days/year. However, during the relatively rainy years, the total of rainy days is ranging from 10 to 38 days/year at Jubbah and Ha'il, respectively. So, the actual mean of daily rainfall obtained by the proportion of the cumulus of annual rainfall and the cumulative frequency of rainy days during the studied period varies from 4.1 to 10.5 mm/day at Ha'il and Faydat Ibn Suwaylim, respectively. But the maximum of daily rainfall increases from 10.5 mm/day (2013) to 42.5 mm/day (2006) and the difference between the upper and lower mean varies from 9.6 to 41.9 mm/day at Ha'il and Jubbah, respectively. So the actual mean of daily rainfall is characterized by the high coefficients of variation, with 0.44 to 1.11 at Faydat Ibn Suwaylim and Jubbah, respectively (Figure 2C). Accordingly to the variability of daily rainfall, the maximum daily rainfall observed during the studied period, varies from 11.4 to 25.2 mm/day at Jubbah and Al Ha'it, respectively (Figure 2D). Consequently, the range values show that the maximum is observed with 73.5 mm/day at Faydat Ibn Suwaylim and the minimum with 30.9 mm/day at Ha'il. So, the variability of maximum daily rainfall is characterized by the high coefficients of variation, ranged between 0.47 at Al Hait to 0.71 at Jubbah.



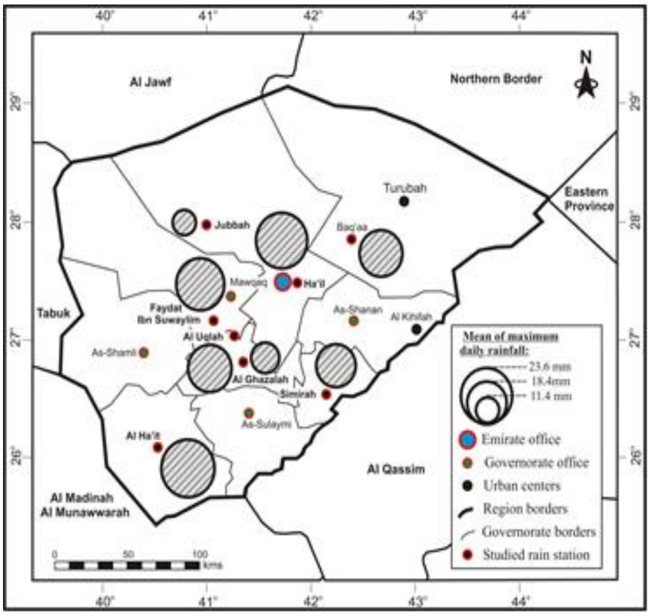

**A:** Spatial distribution of mean annual rainfall




**B:** Spatial distribution of cumulative rainy days




**C :** Spatial distribution of mean daily rainfall.




**D :** Spatial distribution of mean maximum daily rainfall

**Figure 2:** The spatial distribution of annual and daily rainfall

### *3.1.2 Standardized Anomaly Index (SAI) of rainfall*

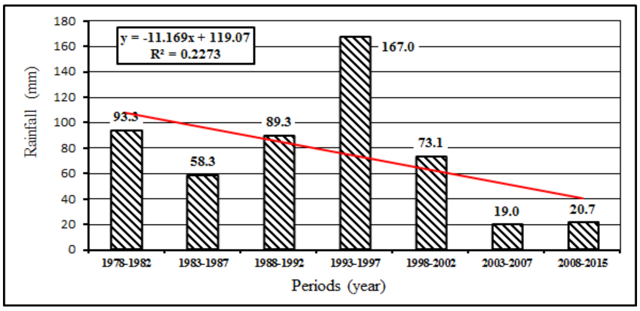
Positive values that suggest wet years relative to the period of reference increase from 14 years at Al Hait and Jubbah, 15 years at Ha'il, 16 years at Al Ghzalah, Al Uqlah and Baq'aa to 18 years at Simirah and Faydat Ibn Suwaylim. While the Positive values that suggest wet years relative to the period of reference increase from 14 years at Al Hait and Jubbah, 15 years at Ha'il, 16 years at Al Ghzalah, Al Uqlah and Baq'aa to 18 years at Simirah and Faydat Ibn Suwaylim. While the negative ones imply a drought condition during the dry years vary from a station to another with the maximum of 24 years at Al Hait and Jubbah to the minimum of 20 years at Simirah and Faydat Ibn Suwaylim.

To analyze the statistical significance of the SAI variance, the Chi square test was computed. The test Chi square distribution has been used for detecting the statistical significance of the SAI variance. The null hypothesis indicating that the variance data don't have any outliers is accepted if the computed value of Chi square test is greater than the critical value at 0.05 significance level corresponding to the degree of freedom (n - 1). While the null hypothesis is rejected and the alternative hypothesis is accepted on the contrary case. In total of the studied stations, the Chi square calculated values are smaller than the critical values at 0.05 significance level with 3.705 at Al Uqlah to 6.211 at Al Hait.

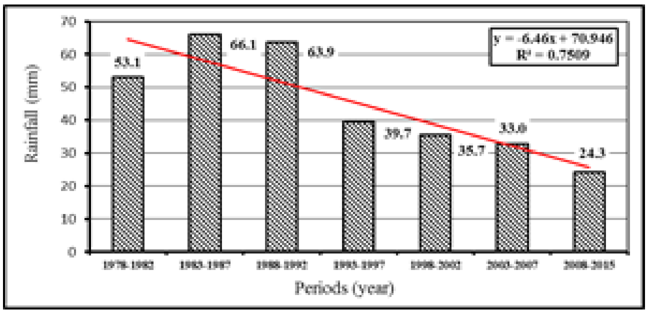
### 3.2 Trends analysis of annual rainfall

### *3.2.1 Moving-averages of annual rainfall*

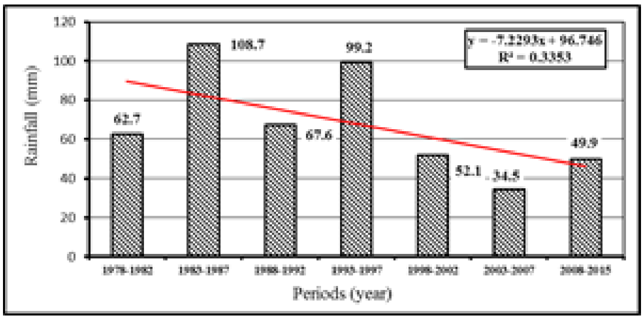
The analysis of the annual rainfall for 1978-2015, indicates downward trend with a decrease ranged from 4 mm to 167 mm in 38 years at Jubbah and Simirah, respectively. So, a decreasing annual mean varies from 0.1 mm/year at Jubbah to 1.8 mm/year at Simirah. Accordingly, the decreasing trends of annual rainfall were analyzed using the Moving averages method. So, the time-series of dataset was divided into seven periods: 1978-82, 1983-87, 1988-92, 1993-97, 1998-2002, 2003-2015. The Figure 3 presents the moving-averages of the named periods.



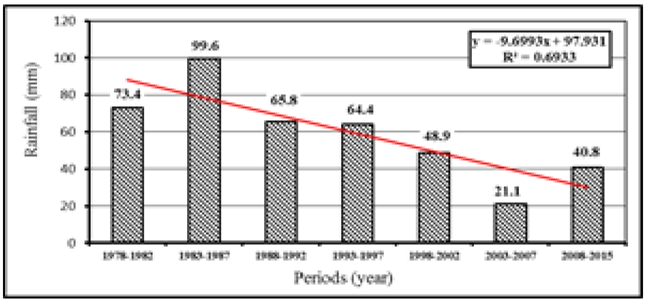

**A : Simirah.**



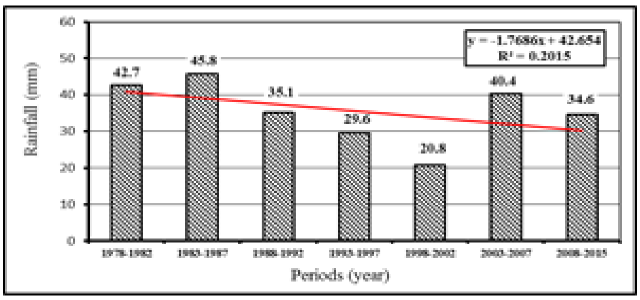

**B : Al Hait.**



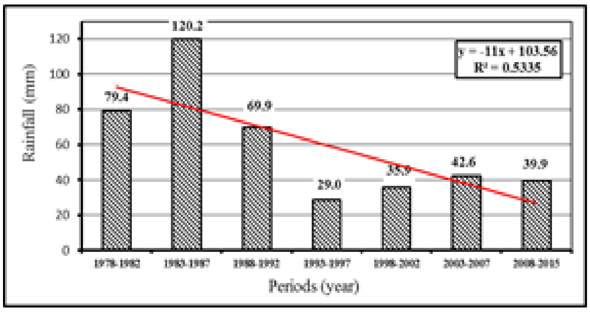

**C : Faydat Ibn Suwaylim.**



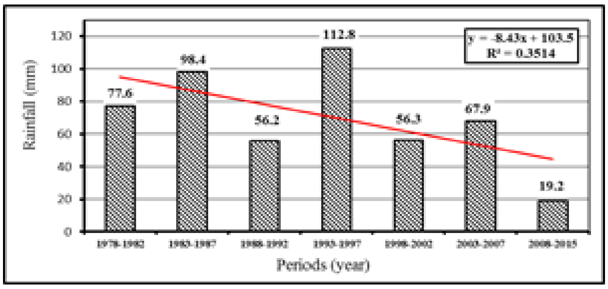

**D : Al Ghazalah.**



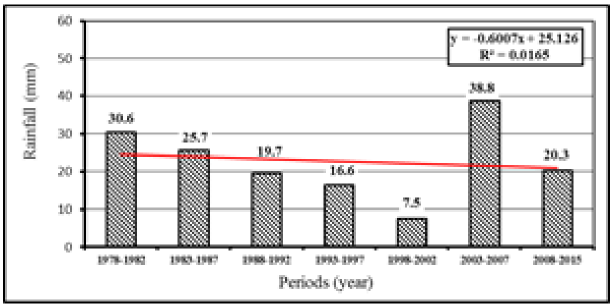

**E : Ha'il.**




**F : Al Uqlah.**




**G : Baq'aa.**




**H : Jubbah.**

**Figure 3:** Moving averages of annual rainfall.

### *3.2.2 Homogeneity of variance of annual rainfall*

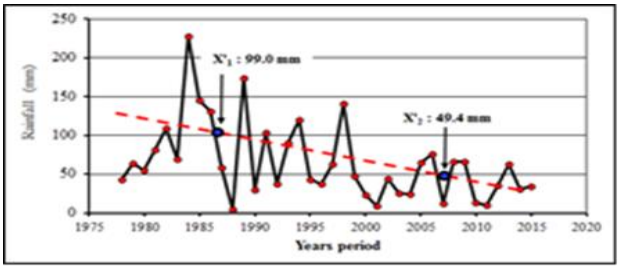
There is no homogeneous trends characterizing the same period at all station. But, in general, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). From these various trends, it is clear the difficulties to determine the main trend of annual rainfall in all stations using the moving-average method. However, the semi-averages method was applied to analyze the annual rainfall trends.

The variance is homogeneous if the calculated Fcmax value is small than the critical Ftmax value at the degree of freedom (n-1) and significance level 0.05. It is clear from the data of table 10 that the calculated Fmax values are greater than the critical Fmax value 2.46 at the statistical significance level 0.05 and the degree of freedom 18. The results of this test indicate that the variance is homogeneous at all stations, except at Baq'aa station.

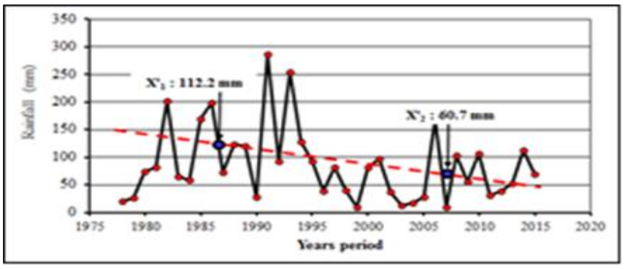
### *3.2.3 Semi-averages of annual rainfall*

Trend analysis of a series of observed annual rainfall using the semi-averages method can indicate if the rainfall pattern and distribution is changing in due course of time or remains stable (Borse and Agnihorti, 2017). Various researchers have contributed to the study of climate change over Saudi Arabia using rainfall and temperature trends. So, the analysis of different time series data have proved that rainfall trend is decreasing and temperature trend is increasing (AlSarmi and Washington, 2013). The rainfall and temperature have a direct impact on the scarcity of the surface water resources over Saudi Arabia (Amin et al., 2016).

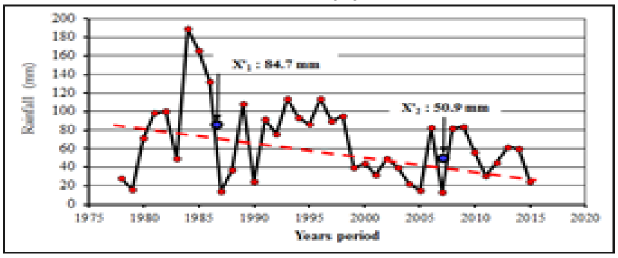
In general, some measures of central tendency (mean, mode, median); measures of position (location) ($Q_1$, $Q_1$, $Q_3$); and measures of dispersion (Sd, IQR, Range, ...) are used to describe the amount or rate of the variability of meteorological events. In this study, the whole data of rainfall is divided into equals periods (parts) : (1978-1996) and (1997-2015). After the data has been divided an average (arithmetic mean) of each part is calculated in order to obtain 2 points. On the graphic of rainfall distribution, every point is plotted against the middle of each part. Then, the straight line joining these 2 points gives the trend line. So, the table 11 and figure 4 summarize the annual rainfall trends using the semi-averages method.



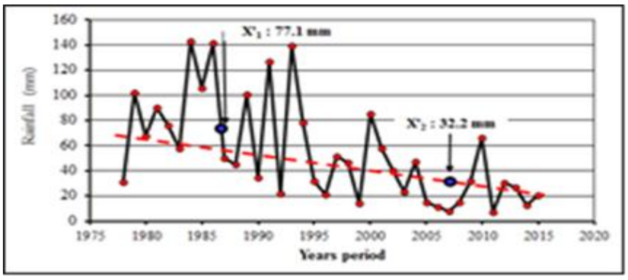

**A : Simirah**



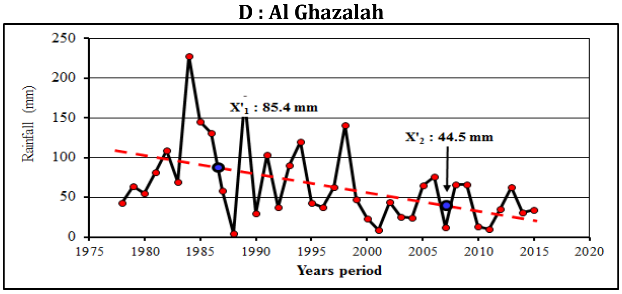

**B : Al Hait**



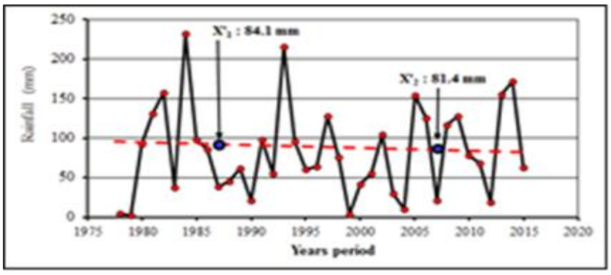

**C : Faydat Ibn Suwaylim**



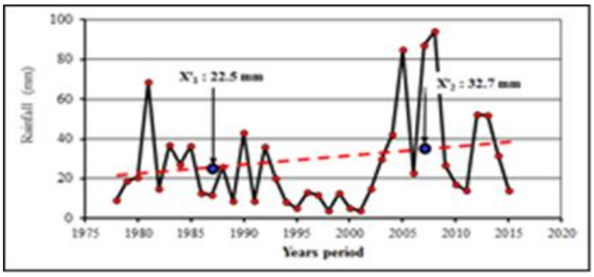

**D : Al Ghazalah**




**E : Ha'il**




**G : Baq'aa**




**H : Jubbah**

**Figure 4:** Semi averages of annual rainfall.

The figure 4 represents the annual rainfall trends using the semi-averages of rain ($X_1$,$X_2$) were calculated for each half period ($n_1$,$n_2$) and the slope estimator (b) of the trend line. The line trend joins the two points of semi-averages.

In general, the annual rainfall amounts have decreasing rain trends in all stations, except Jubbah. It was found that all trends had simple negative regression values ranged between (-2.711) in Al Hait and (-0.142) in the Baq'aa, while it reached 0.537 in Jubbah. The statistical significance was determined using the standard error method S.E$|X'_1-X'_2|$ for the two semi-averages. There are statistically significant differences between the two semi-averages in all stations, at the 5% significance level, except Baqa'a and Jubbah stations. So that, all the differences between them were greater than twice the standard error.

These differences are statistically significant because the probability of their occurrence exceeds 5%. For the difference to be statistically significant and therefore substantial and real, it is required that it exceed (2S.E) or (3S.E). Otherwise it is considered statistically insignificant and rejected (Gregory, 1970; Crowe, 1971). Accordingly, all the rain trends represented the regression lines between the negative semi-averages are statistically significant. But, the increasing trend in the Jubbah station is considered to be due to the randomness of the annual rainfall system.

Student's t-statistic test of the difference between the semi-averages also confirmed these results. the calculated "t" values are greater than the critical "t" value (1.688) at the significance level 0.05, at the degree of freedom (n-2) 36 in all stations except Baq'aa and Jubbah. So, the difference between the semi-averages of annual rainfall can to be significant, if the calculated "t" value is greater than the critical "t" value at the significance level of 0.05 and the degree of freedom at the station. Accordingly, the decreasing rain trends are significant and can be relied upon in analyzing the temporal and spatial changes of annual rainfall in Hail region, except the rain trends in Baq'aa and Jubbah stations.

## 4. Conclusions

Ha'il region is susceptible to climate variability and change like various regions in Saudi Arabia. the trends analysis of annual rainfall and mean and extreme daily temperature for the period show that the fluctuations or variations in climatic parameters is a recurring phenomena in the studied stations. The effects of climate variability exacerbate existing social and economic activities, because people are sensitive to climate variability. Rainfall and temperature are the most determinant climatic parameters in the arid zones such as Ha'il region. The present study used the rainfall and temperature of the meteorological data and the time series for the period (1978-2015), to conducting descriptive statistics and trend analysis. The variability analysis, is conducted using the coefficient of variation **(CV).** The range of annual rainfall varies from 70.4 mm to 280.8 mm at Ha'il and Simirah,respectively. Inter-annual variability of rainfall is characterized by the high coefficients of variation, from 0.59 at Ha'il to 0.87 at Jubbah. In the same context, the cumulative frequency of rainy days during the period of 1978-2015 (38 years) shows that the maximum is observed with 460 days at Ha'il and the minimum with 161 days at Jubbah. Consequently, the rainy days varies from 5 days/year at Jubbah to 13 days/year at Ha'il. So the actual mean of daily rainfall is characterized by the high coefficients of variation, with 0.44 to 1.11 at Faydat Ibn Suwaylim and Jubbah, respectively. In addition, the values of Chi square test reveals the significant Standardized Anomaly Index (SAI) of rainfall.

The trend analysis of rainfall, using Moving-averages indicates downward trend with a decrease ranged from 4 mm to 167 mm in 38 years at Jubbah and Simirah, respectively. A decreasing annual mean varies from 0.1 mm/year at Jubbah to 1.8 mm/year at Simirah. Accordingly, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). In the same context, the Homogeneity of variance using Fmax-

Hartley's ratio indicates the homogeneous variance with the calculated $F_{max}$ values greater than the critical $F_{max}$ value 2.46 at the statistical significance level 0.05 and the degree of freedom 18 in all stations, except at Baq'aa station. The results of the Semi-averages method also show a significant decreasing trends in all stations, except Jubbah. It was found that all trends had simple negative regression values ranged between (-2.711) in Al Hait and (-0.142) in the Baq'aa, while it reached 0.537 in Jubbah.

These results indicate that the climate of Ha'il region is affecting by the increasing rainfall trends in recent decades, which may have severe socioeconomic repercussions in many sectors especially the agriculture and surface water resources.

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## References

Abdou, A. E. A. 2014. *Temperature trend on Makkah, Saudi Arabia*. Atmospheric and Climate Sciences, 4, Pp. 457–481.

Alghamdi, A. S., and Moore, T. W. 2014. Analysis and comparison of trends in extreme temperature indices in Riyadh City, Kingdom of Saudi Arabia (1985–2010). Journal of Climatology, 2014, Article 560985. https://doi.org/10.1155/2014/560985

Almazroui, M., Islam, M. N., Athar, H., Jones, P. D., and Ashfaqur, R. 2012. Recent climate change in the Arabian Peninsula: Seasonal rainfall and temperature analysis of Saudi Arabia for 1979–2009. Atmospheric Research, 111, Pp. 29–45.

Almazroui, M., and Saeed, S. 2020. Rainfall trends and extremes in Saudi Arabia in recent decades. Atmospheric Research, 11, 964.

AlSarmi, S. H., & Washington, R. 2013. Changes in climate extremes in the Arabian Peninsula: Analysis of daily data. International Journal of Climatology. https://doi.org/10.1002/joc.3772

Amin, M. T., Mahmoud, S. H., and Alazba, A. A. 2016. Observations, projections and impacts of climate change on water resources in the Arabian Peninsula: Current and future scenarios. Environmental Earth Sciences, 75, 864.

Asfaw, A., Simane, B., Hassen, A., and Banditer, A. 2018. Variability and time-series trend analysis of rainfall and temperature in North Central Ethiopia: A case study in Woleka sub-basin. Weather and Climate Extremes, 19, Pp. 29–41. https://doi.org/10.1016/j.wace.2017.12.002

Balling, R. C., Jr., Skindlov, J. A., and Phillips, D. H. 1990. The impact of increasing summer mean temperatures on extreme maximum and minimum temperatures in Phoenix, Arizona. Journal of Climate, 3, Pp. 1491–1494.

Barrow, E. M., and Hulme, M. 1996. Changing probabilities of daily temperature extremes in the UK related to future global warming and changes in climate variability. Climate Research, 6, Pp. 21–31.

Basistha, A., Arya, D. S., and Goel, N. K. 2008. Analysis of historical changes in rainfall in the Indian Himalayas. International Journal of Climatology, 29, Pp. 555–572. https://doi.org/10.1002/joc.1706

Borse, K., and Agnihorti, P. G. 2017. Trend analysis of Upper Godavari Basin: A case study. In 22th International Conference on Hydraulics, Water Resources and Coastal Engineering (HYDRO-2017), Ahmedabad, India.

Chu, D. P. T., and Sutradhar, B. C. 1995. On Cochran's and Hartley's tests for homogeneity of variances when observations are autocorrelated. Communications in Statistics – Simulation, 24, Pp. 327–347.

Conover, W. J., Johnson, M. E., and Johnson, M. M. 1981. A comparative study of tests for homogeneity of variances, with applications to outer continental shelf bidding data. Technometrics, 23, Pp. 351–361.

Crowe, P. R. 1971. Concepts in climatology. Grou Ltd.

David, H. A. 1952. Upper 5% maximum F-ratio. Biometrika, 39, Pp. 422–424.

Dong, Z., Jia, W., Sarukkalige, R., Fu, G., and Meng, Q. 2020. Innovative trend analysis of air temperature and precipitation in the Jinsha River Basin, China. Water, 12(11), 3293. https://doi.org/10.3390/w12113293

El-Nesr, M., Alazba, A., and Abu-Zreig, M. 2010. Analysis of evapotranspiration variability and trends in the Arabian Peninsula. American Journal of Environmental Sciences, 6(6), Pp. 535–547.

Fisher, M., and Membery, D. A. 1998. Climate. In S. Ghazanfar & M. Fisher (Eds.), Vegetation of the Arabian Peninsula Pp. 5–38. Kluwer Academic Publishers.

Ganguly, A., Ray, R., and Sharma, C. P. 2015. Analysis of trend of the precipitation data: A case study of Kangra district, Himachal Pradesh. International Research of Granthaalaya, 3(9), Pp. 87–95.

Gregory, S. 1970. Statistical methods and geographer. Longman Group Ltd.

Gupta, R. C. 1987. On the monotonic properties of the residual variance and their application in reliability. Journal of Statistical Planning and Inference, 16, Pp. 325–333.

Hansen, J., Fung, I., Lacis, A., Rind, D., Lebedeff, S., Ruedy, R., Russell, G., and Stone, P. 1988. Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model. Journal of Geophysical Research, 93, Pp. 9341–9364.

Hollander, M., and Wolfe, D. A. 1973. Nonparametric statistical methods. John Wiley & Sons.

Hartley, H. O. 1950. The maximum F-ratio as a short-cut test for homogeneity of variance. Biometrika, 37, Pp. 308–312.

Hasanean, H.,and Almazroui, M. 2015. Rainfall: Features and variations over Saudi Arabia—A review. Climate, 3, Pp. 578–626.

Jain, S. K., and Kumar, V. 2012. Trend analysis of rainfall and temperature data for India. Current Science, 102(1), Pp. 37–39.

Karl, T. R., Knight, R. W., and Plummer, N. 1995. Trends in high-frequency climate variability in the twentieth century. Nature, 377, Pp. 217–220.

Krishna, L. V. 2014. Long-term temperature trends in four different climatic zones of Saudi Arabia. International Journal of Applied Science and Technology, 4(5), Pp. 233–242.

Manley, G. 1974. Central England temperatures: Monthly means 1659–1973. Quarterly Journal of the Royal Meteorological Society, 100, Pp. 389–405.

Machiwal, D., & Jha, M. K. 2008. Comparative evaluation of statistical tests for time-series analysis: Application to hydrological time series. Hydrological Sciences Journal, 53(2), Pp. 353–366.

McKee, T. B., Doesken, N. J., and Kleist, J. 1993. The relationship of drought frequency and duration to time scales. In Eighth Conference on Applied Climatology, Anaheim, CA.

Mearns, L. O., Katz, R. W., and Schneider, S. H. 1984. Extreme high-temperature events: Changes in their probabilities with changes in mean temperature. Journal of Climate and Applied Meteorology, 23, Pp. 1601–1613.

Michaels, P. J., Balling, R. C. Jr., Vose, R. S., and Knappenberger, P. C. 1998. Analysis of trends in the variability of daily and monthly historical temperature measurements. Climate Research, 10, Pp. 27–33.

Nalley, D. 2012. Analyzing trends in temperature, precipitation, and streamflow over Southern Ontario and Quebec using the discrete wavelet transform (Master's thesis). McGill University.

Oliver, J. E. 1981. Climatology: Selected applications. Edward Arnold.

Parker, D. E., Legg, T. P., and Folland, C. K. 1992. A new daily Central England temperature series, 1772–1991. International Journal of Climatology, 12, Pp. 317–342.

Rehman, S. 2010. Temperature and rainfall variation over Dhahran, Saudi Arabia (1970–2006). International Journal of Climatology, 30, Pp. 445–449. https://doi.org/10.1002/joc.1907

Rivest, L. 1987. Bartlett's, Cochran's, and Hartley's tests on variances are liberal when the underlying distribution is long-tailed. Journal of the American Statistical Association, 81, Pp. 124–128.

Rutkowska, A. 2013. Statistical methods for trend investigation in hydrological non-seasonal series. Octa Scientiarum Polonorum, Formatio Circumiectus, 12(4), Pp. 85–94.

Serrano, A., Mateos, V. L., and Garcia, J. A. 1998. Trend analysis of monthly precipitation over the Iberian Peninsula (1921–1995). Theoretical and Applied Climatology, 59(1–2), Pp. 85–90.

Subyani, A. M., and Hajjar, A. F. 2016. Rainfall analysis in the context of climate change for Jeddah area, Western Saudi Arabia. Arabian Journal of Geosciences, 9, 122. https://doi.org/10.1007/s12517-015-2102-2

Tarawneh, Q. Y., and Chowdhury, C. 2018. Trends of climate change in Saudi Arabia: Implications on water resources. Climate, 6, 19 pages. https://doi.org/10.3390/cli3030578

Tarleton, L. F., and Katz, R. W. 1995. Statistical explanation for trends in extreme summer temperatures at Phoenix, Arizona. Journal of Climate, 8, Pp. 1704–1708.