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Spatio-Statistical Analysis of Temperature and Trend Detection in Baluchistan, Pakistan

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Abstract. The assessment of temperature variability in any region of the world is important for prior planning in the context of current climate change. The mean monthly, seasonal and annual temperature data of nine meteorological stations was analysed in this study to determine the temperature variability and trend in Baluchistan province, Pakistan. The non-parametric Mann–Kendall and Sen's slope estimator were applied to investigate the temperature trend pattern in the study Temperature data from the relevant meteorological stations (met-stations) were collected for this purpose from the Pakistan Meteorological Department and the National Center for Environmental Information. The result revealed an increasing significant trend (IST) in the mean annual temperature at Dalbandin, Kalat, Quetta, Zhob and Gawadar meteorological stations. While the seasonal minimum, maximum and mean temperature showed trend fluctuations in winter, spring and autumn seasons. In the seasonal analysis, the increasing trend has been detected in most of the meteorological stations (Dalbandin, Kalat, Quetta, Zhob, Khuzdar, Lasbella, Gawadar) in all four seasons. Whereas in Sibi met-station, a decreasing significant trend (DST) was recorded in summer (minimum, maximum and mean) and the met-station Barkhan recorded decreasing trend in maximum temperature in the autumn season. The Baluchistan province is totally spread over an arid and semiarid area of Pakistan where temperature fluctuations further aggravate the deprived agriculture and sparse natural vegetation.

Keywords: Seasonal temperature Trend, slope magnitude, Mann-Kendall Trend Model, climate change.

1. Introduction

The term "climate change" refers to fluctuation in meteorological variables (temperature, precipitation, solar radiation) that has excited for a long time, and the change in term climate has negative effects for both humans and nature (Izaguirre et al., 2021). Climate change is experienced across the world and its impacts vary from region to region (Trajkovic & Kolakovic, 2009). Temperature and precipitation are considered as the major components that bring fluctuations in global climate system (Önöz & Bayazit, 2003; Khan, 2011; Gu et al., 2016; Di Cecco & Gouhier, 2018). This research focuses on the variability and quantification of trend in temperature in Baluchistan, a province of Pakistan. Numerous studies have been conducted to determine the variation in temperature (Alhaji et al., 2018; Gavrilov et al., 2018; Agbo et al., 2021) and the findings reveal that a systematic examination of this ever-changing and evolving trend is urgently needed. The gradual change in temperature, precipitation and its impacts are observed in different regions of the world (Salma et al., 2012; Bibi et al., 2018). Meteorologists associate the variations in temperature and precipitation with anthropogenic activities (Zhang et al., 2011; Cho et al., 2016). According to the fourth Intergovernmental Panel on Climate Change (IPCC) assessment report, the global mean temperature is increasing and the combined oceanic and surface temperature increased by 0.8°C from 1880–2012 (Pachauri et al., 2014). The global temperature has been rapidly increasing in the past decade, and the frequency of precipitation events is expected to increase, particularly in humid regions (Qu et al., 2020)China</title><secondary-title>Ecological Indicators</secondary-title></titles><periodical><full-title>Ecological Indicators</full-title></periodical><pages>105724</pages><volume>108</volume><dates><year>2020</year></dates><isbn>1470–160X</isbn><urls></urls></record></Cite></EndNote>. The nineteen (19) met-station data (1960–2000) of temperature and precipitation of the Lancang River China, revealed an increase in temperature and a decrease in precipitation rate (Yunling & Yiping, 2005). The past five decade data of Tarim River Basin concluded an increasing trend in temperature and precipitation (Tao et al., 2011; Xu et al., 2010). The Iranian researchers examined different climatic parameters and the result illustrated an increasing trend in temperature (Kousari et al., 2013). A warming trend was observed throughout the year in Saudi Arabia (29 stations), except in winter where a non-significant cooling trend were observed (El-Nesr et al., 2010). In Switzerland a study was conducted to analyse the temperature trend from 1959–2008 using 2 × 2 km gridded dataset and the result showed an annual significant trend with an average increasing trend of 0.35°C (Ceppi et al., 2012). Penereiro and Meschiatti (2018), analyze the temperature trends in Brazil, MK and Pettitt tests were used. They discovered that there were increasing trends of roughly 35%, decreasing trends of 1%, and no trends in 64% as detected by the mean of maximum temperatures. South Asian nations like, India and Pakistan are additionally dealing with a similar issue, 125 meteorological stations in India showed an upward trend in mean minimum temperature and mean maximum temperature (Arora et al., 2005; Ray et al., 2019).

Pakistan is additionally confronting challenges in various meteorological parameters, particularly in temperature which have significantly ascended in the past few decades. Morphologically majority of Pakistan is dependent on agriculture and fall in arid to semi-arid zones with large spatio-temporal variations in temperature (Chaudhry & Rasul, 2004; Rahman et al., 2021). The statistical linear analysis of temperature in Pakistan shown that temperature has been rising 0.6°C per decade (Afzaal et al., 2009). A long-term temperature analysis (1876–1993) revealed that the average increase in temperature was 0.2°C (Singh & Sontakke, 1996). The mountainous regions are more sensitive and fragile to climate change (Yan et al., 2010; Panthi et al., 2015). In the Himalayas, Karakorum and Hindu Kush (HKH) are commonly considered the third pole due to massive volume of snowcapped peaks (Yao et al., 2012; Latif et al., 2020). The glacial coverage in relation to river runoff, reported an increasing trend in temperature and rainfall that resulted fluctuation in river discharge (Dawood, 2018). According to Khan et al. (2021) Pakistan has been raked in 8th position in the global climate risk counties that experience climate change catastrophes.

The researchers used the statistical tool Mann–Kendall trend Model (MKTM) in different parts of the world to obtain consistent and meaningful temperature trend results. The World Meteorological Organization (WMO) recommended MKTM to analyze the temperature trend. Subsequently, a comprehensive investigation of temperature trends is carried out to detect minimum (min), maximum (max) and mean seasonal (winter, spring, summer, autumn) and mean monthly trend for nine met-stations of Baluchistan province, Pakistan by the Mann–Kendall trend model and Sen's slope estimator (SSE). MKTM detects the trend while SSE quantifies the slope of the trend.

2. Material and Methods

2.1 Study Area

Morphologically, the study area (Baluchistan province) is a dry region located in the south-west of Pakistan (Fig. 1). It is geographically located at the latitude 30° to N and longitude 67° to E. The Kharan desert covers the majority of the province in the southwest, while the Baluchistan plateau lies west of the Sulaiman-Kirthar mountains, which extend from northeast to south-east and are covered by dry hills. The province is bordered in the west by Afghanistan, in the south west by Iran. While Arabian Sea is located in the south, Khyber Pukhtunkhwa is in the north, and Sindh and Punjab provinces are located to the east of Baluchistan. Baluchistan covers approximately 44% of the country's area and has only 5% (8 million) of the total population of Pakistan. Balochistan is known as the country's fruit garden, since it grows over 31 different crops, and the province is dependent on agriculture and livestock which contribute more than half (50%) of the GDP of the province (Durrani et al., 2021). Geographically, the province is divided into four major zones, mountainous

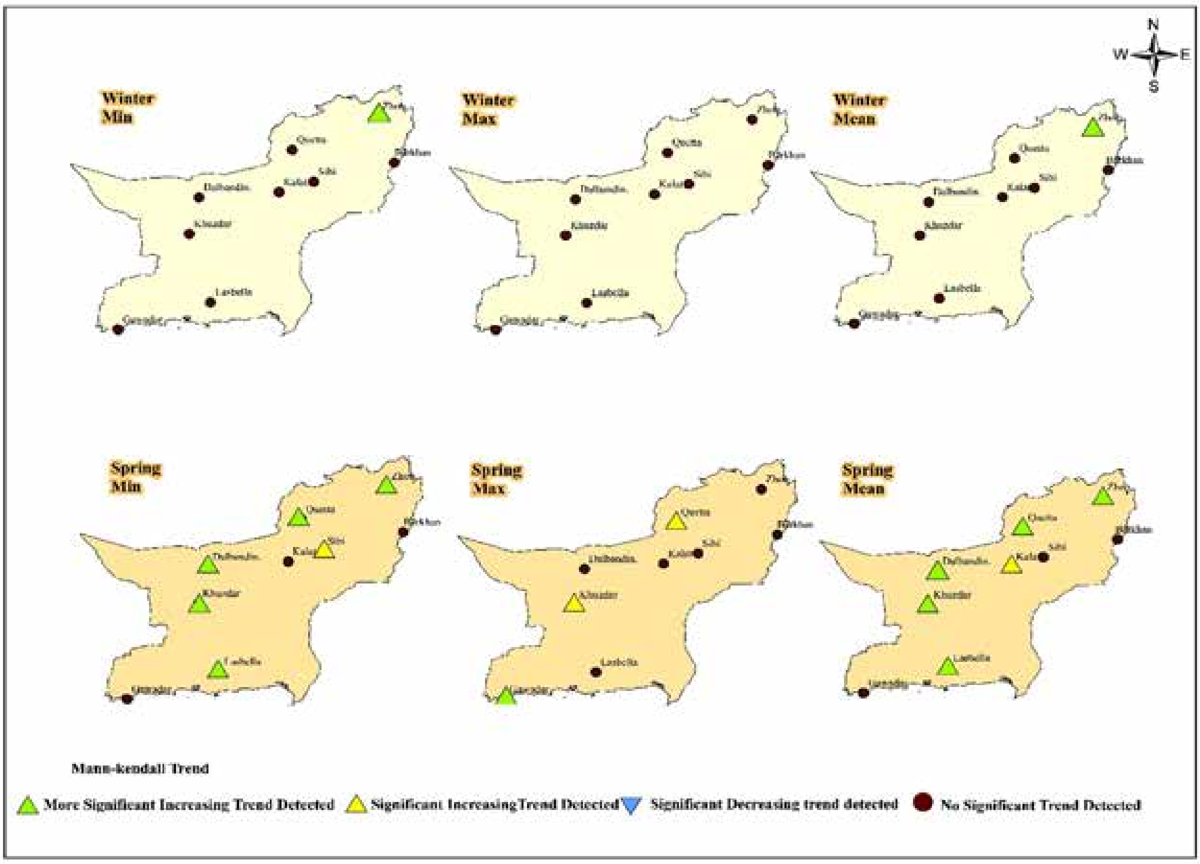

Figure 1. Spatial distribution of meteorological stations in study area

region, plateaus, plains and deserts (Ahmed et al., 2015; Jamro et al., 2020). In these zones the temperature varies, in the higher plateau and mountainous regions, the summer is warm while the winter is cold, on the other hand the lower plateaus are characterised by hot and dry weather in summer, cold in winters whereas, in plain and Kharan desert areas, the summers are extremely hot and the winters are mild.

2.2 Data Collection

The acquired data of mean monthly maximum, minimum and mean temperature data of eight (8) metrological stations have been collected from Pakistan Meteorological Department (PMD) and the data of one met-station (Barkhan) was obtained from National Center for Environmental Information (Table 1). The monthly temperature data was converted into mean annual and mean seasonal. The time series temperature data varies in its observation out 9 met-stations 5 stations (Dalbandin, Kalat, Lasbella, Quetta, Khuzdar) possess 28 annotations, Zhob, Sibi 38, Barkhan 10 and Gawadar possess 17 observations. The collected temperature data was on a daily basis without any gap. Furthermore, the data was processed with Geographical Information System (GIS) using interpolation technique Inverse Distance Weight (IDW) and monthly and seasonal maps were prepared to get accurate result. The seasonal data was analysed by MKTM to detect change in temperature. Similarly, the SSE was applied to annual data to quantify the slope of the trend.

Table 1. Statistical description and Geographical location of temperature in (degree °C) in the selected meteorological stations in the study area

S.no	Met-set	Time Period	Latitude	Longitude	Elevation (in feets)
1.	Barkhan	2009–2018	29.8830°	69.7170°	3602
2.	Dalbandin	1990–2018	28.8830°	64.4000°	2789
3.	Kalat	1990–2018	29.0330°	66.5830°	6617
4.	Lasbella	1990–2018	25.8700°	64.7129°	177
5.	Quetta	1990–2018	30.2510°	66.9380°	5250
6.	Khuzdar	1990–2018	27.8330°	64.1330°	4042
7.	Zhob	1980–2018	31°.21’	69°.28’	15123
8.	Sibi	1980–2018	29°.33’	67°.53’	1431.6
9.	Gawadar	2002–2018	25°.08’	62°.2	97.96

2.3 Mann-Kendall Trend Model (MKTM)

Globally various parametric and non-parametric tests are used to detect hydro-meteorological trend in time series data (Duhan & Pandey, 2013). Mann–Kendall test is a non-parametric statistical tool that does not need the data to be distributed normally. Secondly the test is low sensitive to abrupt breaks due to inhomogeneous time series (Jaagus, 2006). The model is widely used to identify the temperature trend in time scale.

The Kendall's S equation can be drive as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sign(Tj - Ti) \quad (Eq.1)$$

$$Sign(Tj - Ti) = \begin{cases} 0 & if\ Tj - Ti = 0 \\ 1 & if\ Tj - Ti > 0 \\ -1 & if\ Tj - Ti < 0 \end{cases} \quad (Eq.2)$$

To calculate the statistical variance, the following formula has been used:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} ti(ti-1)(2ti+5)}{18} \quad (Eq.2)$$

MKTM was applied to temperature data of nine meteorological stations. In the MKTM, if the p (probability) value is less than (≤) the level of significance (α) =0.05, it indicates that null hypothesis (H_0) is rejected which means that statistically significant trend is present. On the other hand, if the p value is greater than (≥) the level of significance (α) =0.05, the null hypothesis (H_0) will be accepted that indicates that the trend is not statistically significant in the time series data. The correlation coefficient of Mann-Kendall is represented by, the greater value of indicate the stronger association and vice versa. Moreover, the statistical variance value (S) indicates the increasing (upward) or decreasing (downward) trend.

2.4 Sen's Slope Estimator (SSE)

If the magnitude of linear trend is present, then true slope can be determined by using non-parametric approach introduced by Sen's Slope Estimator. The slope estimates of entire time series data are calculated using the following equation:

$$Q_i = \frac{X_i - X_j}{j - k} \quad (Eq.4)$$

The values of N and Q_i is Sen's estimators of slope. The odd values of N can be computed as:

$$Q_{med} = T\,(N+1)/2 \quad (Eq.5)$$

Similarly, if N values is even then it can be express as:

$$Q_{med} = \frac{T\left(\frac{N}{2}\right) + T(N+2)}{2} \quad (Eq.6)$$

where in Eq. (4), Xi and XK are the data pairs values at time j and ($j > k$), respectively, whereas i = 1, 2, 3, 4, 5… … … N. The SSE has been expressed by the median of values of Ti.

$$Q_{med} = \begin{cases} Q\left[\frac{N+1}{2}\right], & if\ N\ is\ odd \\ \frac{Q[N/2] + Q[(N+2)/2]}{2}, & if\ N\ is\ even \end{cases} \quad (Eq.7)$$

Finally, the non-parametric model the Q_{med} has been determined to get true slope and magnitude. If Q_i shows positive value then there will be an upward or increasing trend in the time series data, and if Q_i shows negative value then it reveals the downward or decreasing trend. Whereas, zero value indicates no trend. At last the resultant unit Q_i would be original units of slope magnitude per year or percent per year (Salmi et al., 2002). Within Addinsoft XLSTAT MKTM and SSE were used to analyze the temperature time series data to find positive or negative trend in temperature and slop magnitude Q_i. ArcGIS 10.8 version has been used to prepare the interpolation maps and spatial database.

3. Analysis and Results

3.1 Annual Mean Temperature Trend (TAMean) Analysis

The Mann-Kendall and Sen's slope estimators were applied to all nine met-stations of various time series temperature data (annual mean temperature, seasonal max, min and mean). The elevation and time series of all met-stations are figured out in (Table 1). The monthly mean temperature varies with its highest and lowest values. The highest values in terms of Mean Monthly Temperature (TMMean) were recorded mostly in the month of July at Sibi (35.9°C) followed by Dalbandin (34.9°C), Lasbella (32.7°C), Khuzdar (30.8°C) meteorological stations. However, in other met-stations the temperature was slightly lower such as in Kalat 24.6°C, Barkhan 26.5°C, Quetta 29.1°C in same month (July). Whereas, in case of lowest (TMMean) recorded in January where Kalat possessed 3.3°C followed by Quetta 4.9°C Zhob 6.5°C, Barkhan and Dalbandin 10.7°C, Khuzdar 10.9°C, Sibi 14.2°C, Lasbella 17.8°C while highest value (TMMean) was possessed by Gawadar 18.6°C among all nine met-stations in the month of January. The above analysis revealed that highest (TMMean) was recorded in July, while in January possessed the lowest (TMMean). The lowest temperature was observed higher elevation values Kalat (24.6°C) with elevation values 6,617 ft, followed by Barkhan (26.5°C) 3,602 ft and Quetta (29.1°C) with elevation value 5,250 ft

Table 2. The Monthly Mean Temperature data of nine stations in Baluchistan province

Met-stations	Temp (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	SD
Barkhan	Mean	10.7	11.7	14.3	14	15.7	19	26.5	23.1	23.8	21.3	18.4	12.9	5.2
Dalbandin	Mean	10.7	13.5	18.8	25.2	30.7	33.5	34.9	32.8	28.8	23	16.9	11.7	8.9
Kalat	Mean	3.3	5.4	9.2	14.7	19.3	22.5	24.6	23.2	18.9	13.4	8.4	5.7	7.6
Lasbella	Mean	17.8	20.2	24.7	29.6	33.1	33.9	32.7	31.4	30.8	28.8	23.9	19.5	5.7
Quetta	Mean	4.9	7.4	12.5	17.9	23.1	27.2	29.1	27.5	22.7	16.4	11.1	6.5	8.7
Khuzdar	Mean	10.9	13.1	18.2	23.3	28.5	30.1	30.8	30.6	27.1	22.7	17.1	12.8	7.5
Zhob	Mean	6.5	8.8	14.2	20.4	25.8	29.4	29.5	28.8	26.1	20.3	14	8.8	8.7
Sibi	Mean	14.2	17.4	23.2	29.9	35.7	37.8	35.9	34.3	32.7	28.1	21.6	15.9	8.5
Gawadar	Mean	18.6	20.4	23.7	27.7	30.7	31.4	30.4	29.4	28.3	27.6	24.5	20.2	4.5

respectively. In the context of standard deviations (SD) Dalbandin 8.9 Quetta, Zhob have the same SD 8.7, Sibi 8.5, Kalat 7.6, Khuzdar 7.5, Lasbella 5.7, Barkhan 5.2 and Gawadar have the lowest SD 4.5 (Table 2).

The MKTM was also applied to the Annual Mean Temperature (TAMean) for all meteorological stations in the study area. The results of the MKTM revealed that more significant trends and significant trends were observed in (TAMean) for most met-stations. More significant and significant temperature trends with p (probability) values were found in Kalat (0.00), Quetta (0.00), Zhob (0.01), Dalbandin (0.04), and Gawadar (0.05) met-stations that rejected the Null hypothesis (H0). The Kendall's tau distinguishes Kalat with more trend amongst all other stations, and statistical variance (S) quantifies the increasing trend observed in all these met-stations (Table 3). The results of the Mann–Kendall trend (TAMean) indicates that the met-stations with more elevations and increasing population rate having upward trend (Kalat, Quetta, Zhob, Dalbandin, Gawadar). The 2017 census shown that more than 60–70 percent of papulation was increased in majority of met-stations except Sibi and Gawadar (Nawaz-Ul-Huda & Burke, 2017). The population has diversified effects on development. Whereas the relationship between climate change and development is directly proportional. In developing societies (population growth) influences the emissions of greenhouse gases, which are responsible for climate change (Mondal & Sanaul, 2019). The results also quantify that increasing temperature trends are found in arid to semi-arid regions of Baluchistan province (Kalat, Quetta, Zhob and Dalbandin).

Table 3. MKT results for mean annual temperature for selected 9 stations

Met-stations	Kendall's tau	Mann–Kendall statistics	P-value (Two-tailed)	Model Interpretation
Barkhan	-0.6	-9	0.14	No Trend Detected
Dalbandin	0.2660	108	0.04	Increasing Trend Detected
Kalat	0.4138	168	0.00	Increasing Trend Detected
Lasbella	0.0887	36	0.52	No Trend Detected
Quetta	0.4069	165	0.00	Increasing Trend Detected
Khuzdar	0.2315	94	0.08	No Trend Detected
Sibi	-0.0243	-18	0.84	No Trend Detected
Zhob	0.2740	203	0.01	Increasing Trend Detected
Gawadar	0.3529	48	0.05	Increasing Trend Detected

3.2 Seasonal Mann-Kendall Test

Spatial distribution of met-stations with significant and no significant trend for seasonal data series of different periods are presented in Figure 3 and Table 3. The increasing, decreasing significant temperature trends and annual change point in Max Mini and Mean temperature of different seasons in their Mean, Minimum and Max temperature was detected by using Mann-Kendell trend model (Table 3). In case of winter the Zhob met-station has significant trends in winter minimum temperature (WTmin) and winter mean temperature (WTmean) for both the change point was noticed in 1999. While no trend (NT) was found in other stations and winter maximum temperature (WTmax) (Fig. 4). The probability (p) value for the (WTmin) of Zhob stations is 0.01whereas, in (WTmean) (p) value for Zhob station is 0.00 respectively, that is less than the alpha value (0.05), it means that (H_0) has been rejected which indicates a significant trend in the temperature. The coefficient Tau values for both (WTmean) and (WTmin) for Zhob station are the same. Where the statistical variance value (S) for (WTmin) 6826.7 and (WTmean) 6831.7 of Zhob met-station that indicates increasing trend.

The Mann-Kendell trend (MKT) test result shows a frequent trend was observed in spring season. Majority of the met-stations indicates significant trend in spring minimum and mean temperature. The meteorological stations that shows significant trend in spring minimum temperature (STmin) are Zhob, Quetta, Sibi, Khuzdar,

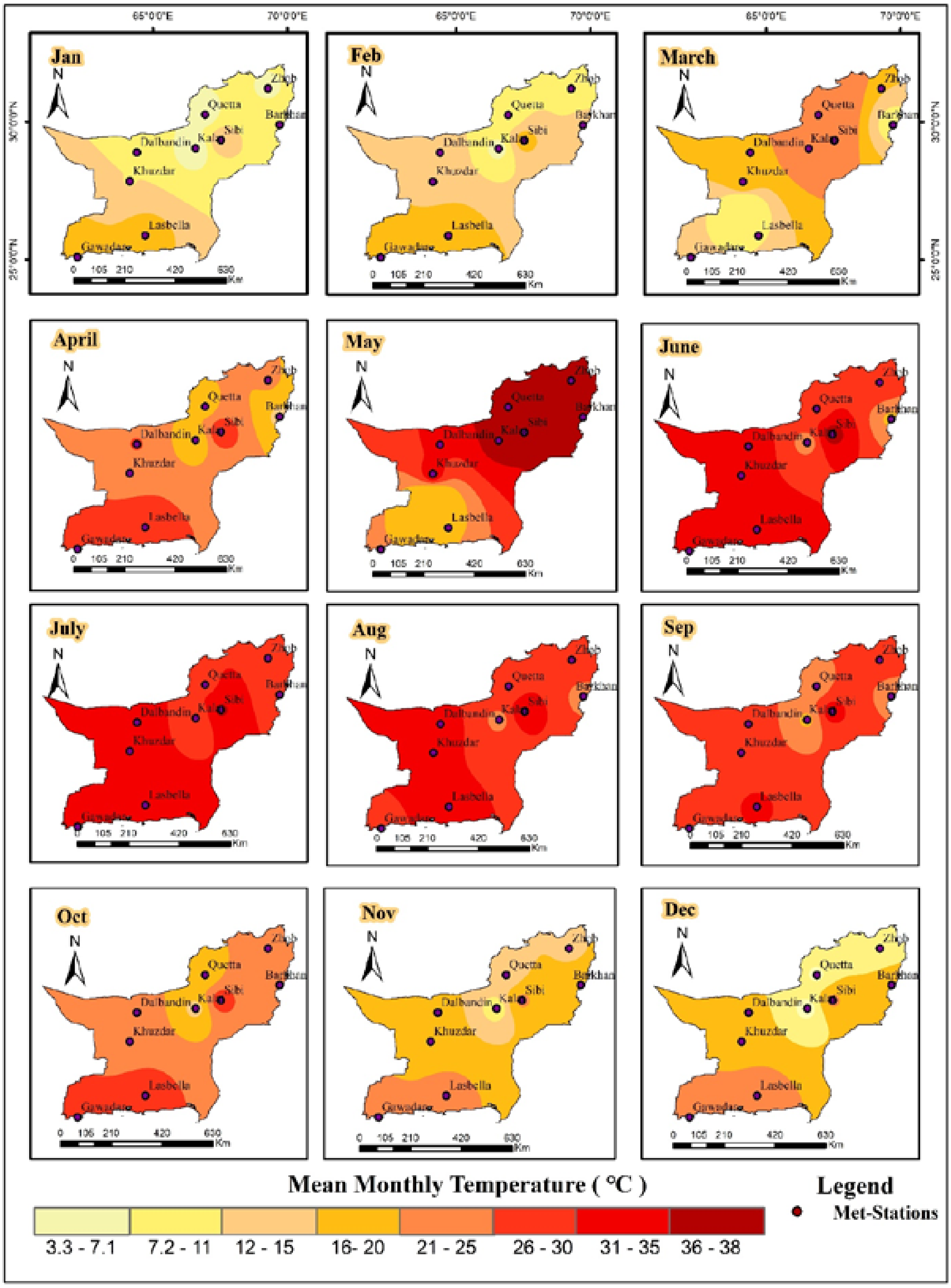

Figure 2. Spatial distribution of meteorological stations with mean monthly temperature

Dalbandin and Lasbella met-stations. The probability (p) value for the (STmin) of Zhob (0.01), Quetta (0.00), Sibi (0.05), Khuzdar (0.01), Dalbandin (0.01) and Lasbella (0.03) respectively. These value indicated that (H0) has been rejected which indicates a significant trend in the temperature. Moreover, Kendall's tau for Quetta met-station is 0.39 which is comparatively shows more statistical significant trend then Dalbandin (0.36), Khuzdar (0.32), Zhob (0.30), Lasbella (0.28) and Sibi (0.22) respectively. Where the statistical variance values (S) for (STmin) indicates upward trend table. In the case of Spring mean temperature (STmean) the trend was detected with probability value (p) in Zhob (0.01), Quetta (0.00), Dalbandin (0.00), Kalat (0.05), Khuzdar (0.00) and Lasbella (0.02) met-stations. probability value (p) of following stations rejected (H_0) that indicates trend in temperature. The coefficient Tau for Khuzdar (0.44) station is more significant values followed by Quetta (0.39), Dalbandin (0.38), Zhob (0.28), Lasbella (0.30) and Kalat (0.26). Furthermore, the values of statistical variance (S) indicate increasing temperature trend in (STmean). While in context of Spring max temperature (STmax) significant trend is observed in Quetta, Gawadar and Khuzdar with (p) 0.05, 0.01 and 0.05 respectively, that rejected the null hypotheses (H_0) that indicates the significant trend in temperature. The Mann-Kendall Tau value for Gawadar is (0.47) which is comparatively more significant then Quetta and Khuzdar that comprises the same values 0.26. The statistical variance (S) indicate increasing temperature trend in (STmax).

In context of summer temperature, MKTM indicates significant trend is present in summer mean temperature (SuTmean), summer max temperature (SuTmax) and summer min temperature (SuTmin) in only Quetta and Sibi meteorological stations. In Quetta and Sibi trend is detected in (SuTmean), (SuTmax) and (SuTmin) with probability value (p) for Quetta (SuTmin) 0.01, (SuTmax) 0.01and (SuTmean) 0.00 comprises the same 0.01(p) value, while in Sibi met-station with (p) (SuTmin) 0.00, (SuTmax) 0.01 and (SuTmean) 0.00 these values rejected the null hypotheses (H0) that indicates the significant trend in temperature. The correlation coefficient Tau for (SuTmean) of Quetta 0.47 with more significant value then Sibi station (-0.33) which shows slight trend. The statistical variance (S) quantify upward trend in Quetta station while downward trend in Sibi station.

The Mann-Kendell trend test indicates trend in autumn season. The trend was observed in both autumn min temperature (ATmin), and autumn mean temperature

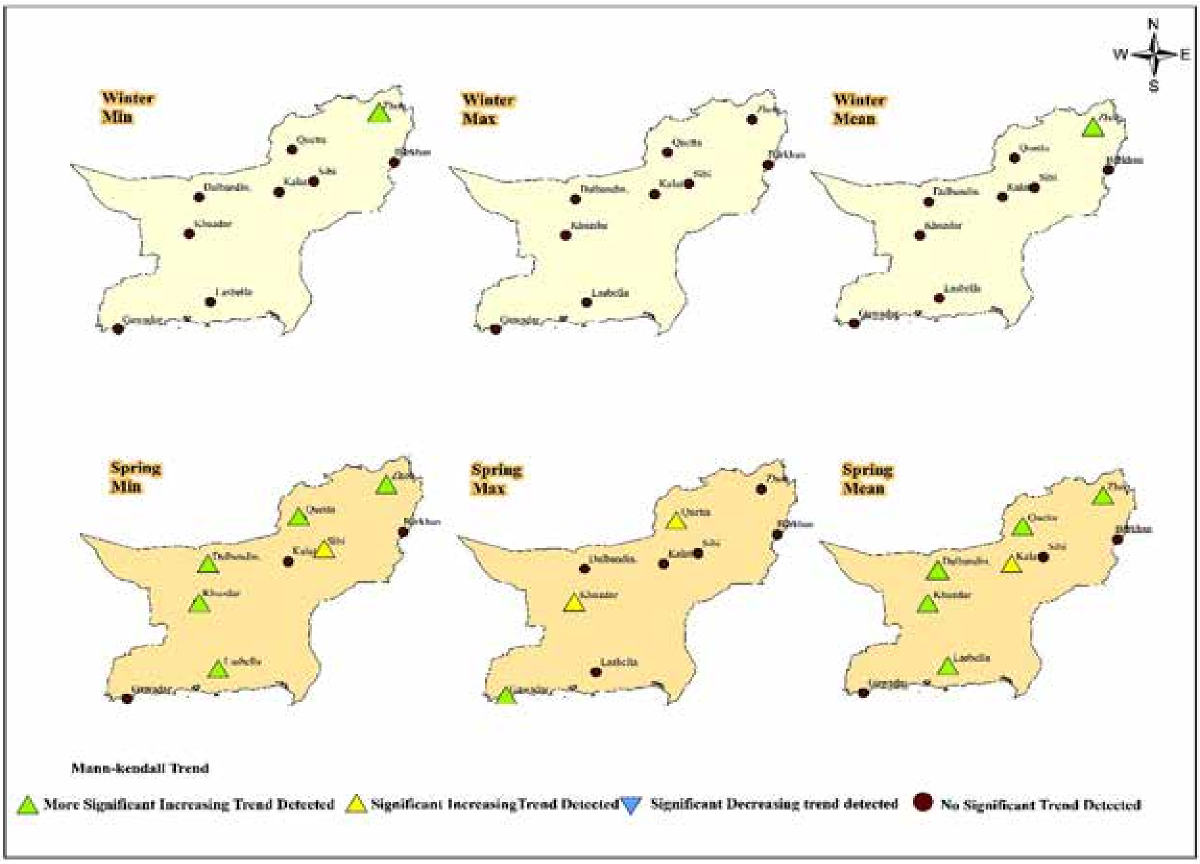

Figure 3. Spatial distribution of met-stations with increasing and decreasing trend in winter and spring seasons

(ATmean). Where the null hypotheses of Gawadar station were rejected by probability value (p) of (ATmin) 0.04 and the (ATmean) 0.00 respectively. A Barkhan met-station shows trend in autumn max temperature (ATmax) with (p) 0.02 which rejects the null hypotheses and indicated temperature trend. The temperature trends were observed meanly three in met-station for autumn mean temperature (ATmean) Quetta and Khuzdar with probability (p) value 0.00 and 0.01 respectively which rejected the (H0) and indicated trend in temperature. The Kendall tau value of Gawadar met-station indicates more significant trend (0.50) then Quetta (0.39) Khuzdar (0.35) and Barkhan value -0.87. Meanly in Autumn season the Statistical variance (S) shows both increasing and decreasing trend (S) values of Gawadar, Quetta and Khuzdar shows upward trend while (S) value of Barkhan indicates downward trend (Fig. 3). Globally, the researchers are agreed that significant increasing and decreasing trend in temperature is mainly caused by urbanization, industrialization, growth in papulation, forest cutting and agriculture revolution (Hosseini et al., 2013).

This paper shows seasonal climatic (winter, spring, summer, autumn) variation found in different regions of Baluchistan. The spring is typical among four seasons where majority of stations (Zhob, Quetta, Sibi, Dalbandin, Khuzdar, Lasbella) show increasing trend, except Kalat, Gawadar, Barkhan. Whereas, other three seasons a few stations show increasing temperature trend such as in Winter (Zhob), Summer (Quetta) Autumn (Quetta, Zhob, Khuzdar). While in some stations like Sibi (Summer) and Barkhan (Autumn) show decreasing temperature trend.

3.3 Sen's Slope Estimator (SSE) Test Result

The annual Sen's slope magnitude of annual temperature is summarized in Table 5. The Sen's slope estimator test result in case of annual mean minimum temperature(TAMMin) the highest value of slope magnitude was recorded in Zhob (Q =0.070), followed by Gawadar (Q =0.023) and Quetta (Q =0.021). While mostly other stations having negative values the lowest slope magnitude has recorded in Barkhan

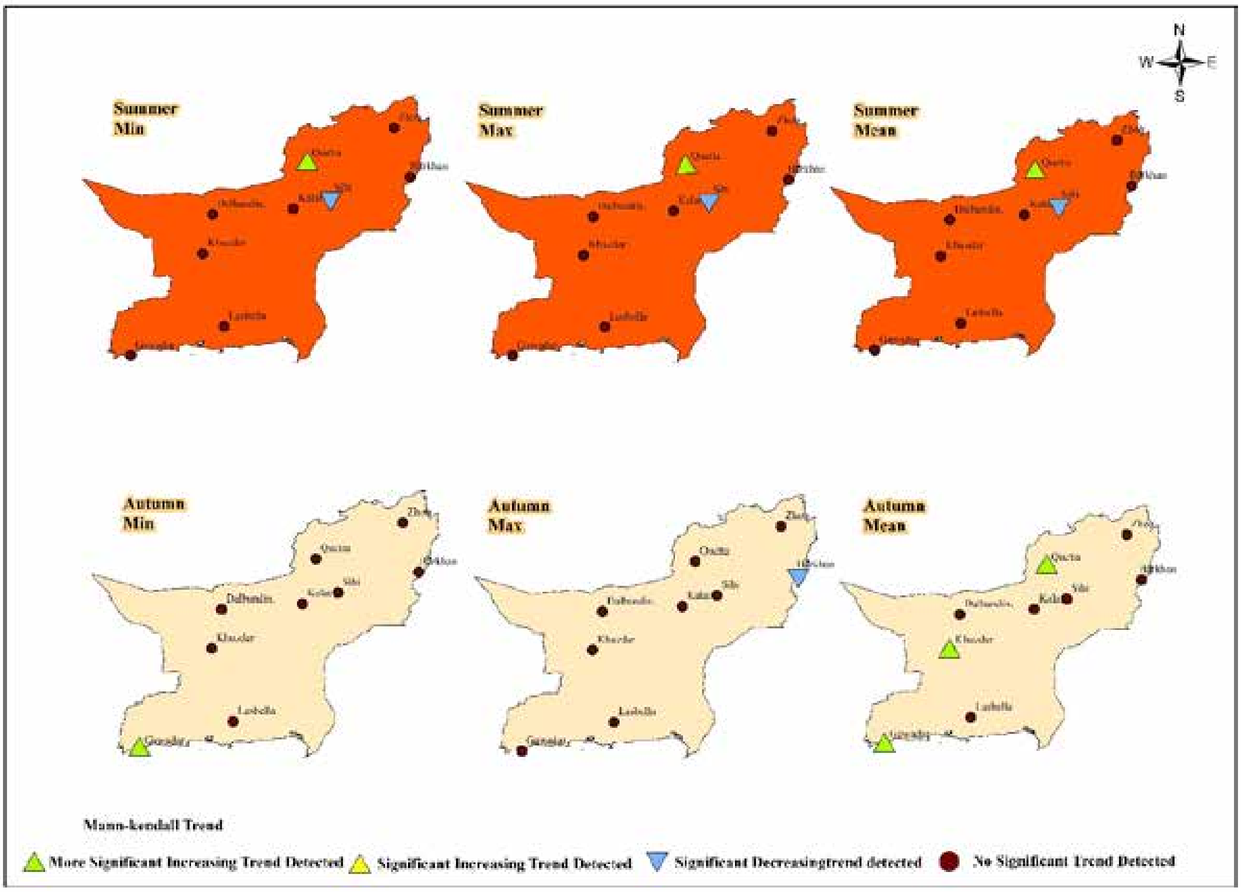

Figure 4. Spatial distribution of met-stations with increasing and decreasing trend in summer and autumn seasons

(Q = -0.083) the remaining stations shows fluctuation in slope magnitude values. The results quantify that the slope magnitude of temperature trend increase in valleys and mountainous regions or lowest atmospheric region then plans or highest atmospheric areas.

Table 4. Sen's slope values for annual temperature of different time period

S.no	Met-stations	(Annual Min SSEM of temp)	(Annual Max SSEM of temp)	(Annual Mean SSEM of temp)
1.	Barkhan	-0.083	-1.199	-0.690
2.	Dalbandin	-0.028	0.021	0.028
3.	Kalat	-0.012	0.030	0.030
4.	Lasbella	-0.034	-0.014	0.013
5.	Quetta	0.021	0.052	0.046
6.	Khuzdar	-0.002	0.002	0.046
7.	Zhob	0.070	0.003	0.031
8.	Sibi	-0.006	-0.050	-0.001
9.	Gawadar	0.023	0.048	0.069

Similarly, the SSE results of annual mean maximum temperature (TAMMax) revealed that highest slope magnitude is recorded in Quetta (Q = 0.052), Gawader (Q = 0.052), Kalat (Q = 0.030) and Dalbandin (Q = 0.021), respectively Khuzdar and Zhob exhibt almost the same values. Whereas, the trend magnitude immensely decrease (negative) in case of Barkhan (Q = -1.199) then rest of stations followed by Sibi (Q = -0.050) and Lasbella (Q = -0.014).

The mean annual temperature (TAMean) SSE test results revealed the Gawadar (Q = 0.069) has the greater (highest) slop magnitude. While the two met-stations show decreasing (negative) trend Sibi (Q = -0.001) and Barkhan (Q = -0.690) exhibit the lowest (negative) magnitude in overall three type of different values. Quetta and Khuzdar having the same increasing Sen's slope magnitude (Q = 0.046) the other remaining stations (Dalbandin, Kalat, Lasbella, Zhob) show fluctuations in case of mean monthly temperature.

4. Discussion

In this research study, the Mann-Kendall and Sen's slope Estimator statistical tests were used to examine spatio-temporal variations in temperature trend of distinct met-stations with varied temperature data (1980–2018). Previous studies have also proven that meteorological parameters like temperature are increasing annually, which brings problems regarding climate change (Agbo & Ekpo, 2021). The analysis revealed that the temperature varies with elevation. In the mean monthly temperature, a low temperature is recorded at high elevation (Table 1) like in Kalat (3.3°C) and Quetta (4.9°C). In contrast, high temperature recorded at low elevation stations like Sibi (37.8°C) and Lasbella (31.4°C). Meanly increasing temperature trends are detected annually as well as seasonally in all stations. The trends are recorded along with elevation, in (TAMean) more significant trends with reference to elevation (Table 1) are the observed in Kalat with p value (0.00), Quetta (0.00), Zhob (0.01), Dalbandin (0.04), and significant trend detected in Gawadar (0.05). The highest slope magnitude by mean of (TAMMin) is recorded in Zhob (Q =0.070) and lowest value is found in negative Barkhan (Q = -0.083). Quetta (Q = 0.052) met-station possess highest slope magnitude and Barkhan (Q = -1.199) has the lowest slope magnitude in (TAMMax). Ashraf et al. (2021), observed an increase of 0.03°C annually in mean temperature in a study conducted in Zhob, Baluchistan analyzing the temperature data from the period 1981 to 2015. The warming trend in Baluchistan was observed at mean temperature from the climate modeling analysis based on mean temperature data over the period 1960 to 2007 recorded total change was 1.5°C (Ashraf et al., 2021). Abbas et al. (2018), conducted a study on the patterns of climate extremes in Baluchistan using different climate indices using 1980–2015 period data that concluded significant changes in extreme temperature and warming climate in the province. Mean annual temperature SSE test results revealed the Gawadar (= 0.069) has the highest slop magnitude whereas, the trend magnitude immensely decreased (negative) in case of Barkhan (= -1.199). In all four seasonally the significant temperature trend is observed also in every met-station. The most affected season among these four was spring, which was the most affected one where positive values indicated increasing more significant and significant trends were detected in mean, min and max temperature in every station except Barkhan. The increasing temperature in spring season is due variability in the amount rainfall that is received from western disturbances in the province. In autumn min and mean positive trend is observed in Quetta, Khuzdar, and Gawadar while Barkhan indicated with negative value shows decreasing trend in autumn max. In winter Zhob, and in summer Quetta shown positive temperature trend. In Sibi met-station negative trend was observed in summer. All these analyses revealed that increasing trend is detected in majority of stations while Sibi and Barkhan show negative (decreasing) trend in summer and autumn max respectively. The increasing temperature trend in summer are due to scarcity monsoon rainfalls (Naz et al., 2020). The increasing summer temperature and dry monsoon affecting the agriculture sector by reducing the crops productivity by 50% as was observed during 1998–2002 (Naz et al., 2020; Ahmad et al., 2004). Among all the four season the most affected station is Quetta, where the temperature trend is detected 7 years (Tab. 4). It is realized that many factors are responsible for gradual increasing temperature trend such as, urbanization, deforestation and temporary migration. According to (Nawaz-Ul-Huda & Burke, 2017) the population of each district such as, Quetta (194.04%), Khuzdar (92.16%), Lasbella (83.66%), Zhob (68.52%), Sibi (30.35%) are increased in two decades respectively. According to some studies, population caused deforestation and the release of greenhouse gases, which are responsible for climate change (Carr et al., 2005; Mondal & Sanaul, 2019). In some areas, seasonal migration is also responsible for increasing population and deforestation that is directly connected to harsh climatic conditions. In winter due to cooled weather conditions, people migrate from remote areas toward cities, like in the mountainous regions of Shirani toward Zhob and from Ziarate to Sibi and Quetta, which increase emission greenhouse gases and deforestation. On the other hand, in hot summer people move from highly temperate areas toward temperate regions such as Sibi, which is the perfect example where population moves to Quetta, Zairate and emission of gases decreases, the summer Mann Kendell result show a declining significant trend in Sibi. It is observed that seasonally affected met-stations (Quetta, Zhob, Khuzdar) are possessed by arid to semi-arid and elevated as well.

5. Conclusion

In this research study, the long-term time series data of annual and seasonal temperature trend of nine met-stations (Baluchistan province) was examined by using Mann-Kendall trend test and Sen's slope approach. The magnitude of significant increasing and decreasing trend in annual and seasonal temperature was calculated, the variations of slope magnitude were mostly found in all met-stations. The statistical tool (MKT) identifies that Kalat, Quetta, Zhob, Dalbandin, and Gawadar stations show more significant and significant trend (increasing) in mean annual temperature, while other stations such as, Barkhan, Lasbella, Khuzdar and Sibi the p value is greater than significant level therefore no obvious significant trend was detected. In case of seasonal temperature, the trend was detected all most in all four seasons but more significant increasing trend was found in all met-stations except Barkhan where no significant trend was detected in spring (STmin, STmax, STmean) season. It is noticeable that in all met-stations increasing trend was found seasonal trend but in summer (SuTmin, SuTmax, SuTmean) Sibi and in autumn (ATmax) Barkhan shows decreasing trend.

The results of SSE revealed that the Zhob (Q = 0.070) station hold highest slope magnitude while majority of stations exhibited negative slope values but Barkhan (Q = -0.083) ranks as the lowest slope magnitude value in mean annual minimum temperature (TMAMin). Similarly, mean annual maximum temperature (TMAMax) the greater value slope magnitude was detected in Quetta meteorological station (Q = 0.052) whereas, Barkhan (Q = -1.199) retains the lower value of slope magnitude. In case of mean annual temperature (TAMean) the two met-stations Barkhan (Q = -0.690) and Sibi (Q = -0.001) hold decreasing (negative) slope magnitude while rest of the stations demonstrate increasing slope magnitude, the highest slope magnitude level was recorded in Gawadar (Q = 0.069) station.

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Data Availability

All data are available by the authors upon request.

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