atmosphere

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The Influence of Teleconnections on the Precipitation in Baluchistan

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Abstract: Precipitation plays a vital role in the economies of agricultural countries, such as Pakistan. Baluchistan is the largest province in Pakistan (in terms of land) and it is facing reoccurring droughts due to changing precipitation patterns. The landscape of the province consists of rugged terrain, mountains, hills, and valleys. The torrential rains lead to devastating flash floods due to the topography of the province, which has proven to be more catastrophic in nature. It is quite intriguing to observe the changing precipitation patterns in Baluchistan. Precipitation has become less frequent but intense, resulting in flash floods and landslides, as well as damage to agriculture, infrastructure, trade, environment, and the ecosystem. Baluchistan is under a drought warning and is already facing a water crisis. This study was performed on monthly precipitation time series data obtained from the Pakistan Meteorological Department (PMD) for determining trends in precipitation from 41 years of data (1977 to 2017) over 13 selected stations in Baluchistan. Due to the non-linear nature of the precipitation data, a non-parametric Mann–Kendall (MK) test was used to determine the increasing or decreasing trends in precipitation on a monthly basis. Large-scale atmospheric circulation and climate indices that affected precipitation were considered to determine their influence on precipitation. Statistical techniques of the partial Mann–Kendall (PMK) and Pearson correlation were applied to each station to ascertain the influence on precipitation due to climatic indices.

Keywords: climate indices; Pakistan; precipitation trends; teleconnections

Citation: Aamir, E.; Khan, A.; Abubakar Tariq, M. The Influence of Teleconnections on the Precipitation in Baluchistan. *Atmosphere* **2022**, *13*, 1001. https://doi.org/10.3390/atmos13071001

Academic Editor: Markus Donat

Received: 6 May 2022
Accepted: 2 June 2022
Published: 22 June 2022

1. Introduction

Teleconnections, also known as climate indices, are mainly responsible for precipitation variations, resulting in flooding and/or droughts. Teleconnections can impact nearby areas to far-flung areas of the world. Atmospheric circulations and climate indices (along with large-scale quasi-stationary atmospheric Rossby waves) strongly control precipitation and droughts around the world. Thus, because different teleconnections have diverse influences, there are alterations in the climates of different regions; for instance, some areas receive more rainfall compared to others; some regions are hotter than the global temperature [1]. Climate variations are mainly due to large-scale ocean circulations, atmospheric circulations, moisture transportation, wind speed, wind direction, heat fluxes, etc. Large-scale ocean circulations have been studied under the influence of teleconnections [2], reflecting our climate patterns [3]. Analyses of teleconnections, impacts, and influences can help to comprehend climate and precipitation patterns [4]. Pakistan, India, and China have experienced unusual flash flooding in the past few decades due to changing torrential precipitation patterns [5–9]. A robust analysis of changing precipitation is very important to understand issues, such as flooding, droughts, landslides, crop destruction, property damage, loss of infrastructure, trade, communication, the environment, economy, biodiversity, ecosystem, etc. [10]. This study also addresses two United Nations Sustainable

Development Goals (SDG), namely SDG no. 11 (sustainable cities and communities) and SDG no. 13 (climate action).

This study is eminent for Pakistan; according to the Global Climate Risk Index (GCRI). Pakistan was ranked the eighth most affected country by GCRI from 1998 to 2017 [11]. Regarding climate related disasters, Pakistan faced 512 deaths and 145 disasters, and a total loss of USD 3.8 billion in a ten-year period (from 1998 to 2017) [11]. Moreover, in 2012, Pakistan was ranked as the third most vulnerable country to climate change [12]. The United Nations Development Programme (UNDP) and the Pakistan Council of Research in Water Resources (PCRWR) report that by 2025 Pakistan will be a water-scarce country (from a water-stressed country) if it does not take serious measures now. The situation is already worsened in Baluchistan (the study area) because water is scarce even now. Moreover, precipitation, which is the main source of water, is decreasing. Baluchistan also suffers from devastating, sporadically-catastrophic flash floods due to unprecedented precipitation [1]. Additionally, the contemporary significance of the region is more critical than ever due to the China–Pakistan Economic Corridor (CPEC) stretching throughout the province and the deep-sea port at Gwadar. This study will be useful for policymakers (i.e., to comprehend the latest situations), in view of climate change and, accordingly, in making policies [13].

Teleconnection indices were employed to study climate variabilities on monthly and seasonal bases. Arctic Oscillation (AO), Indian Ocean Dipole (IOD), El Niño Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Atlantic Multi-decadal Oscillation (AMO), and Pacific Decadal Oscillation (PDO) are commonly used circulation indices to assess precipitation variability over Pakistan. Climate studies, such as [14,15], were conducted to study precipitation variations linked with large-scale atmospheric and ocean circulation indices in the South Asian region. Fewer studies have been undertaken to analyze precipitation variations linked with large-scale atmospheric and ocean circulation indices in Pakistan (Pakistan is one of the most vulnerable countries, according to the Global Climate Risk Index [16,17]). Afzal [18] noted that fresh studies need to be carried out to study the recent influences of NAO on different regions across the globe.

Study [19] used Pearson's correlation to determine the influences of climatic indices, namely NAO, AO, AMO, IOD, PDO, QBO, and ENSO on precipitation with 80% and above significance levels for the positive and negative phases of the indices, separately. It was found that IOD has a positive correlation with its positive phase; the positive phase of AO shows a correlation; PDO shows a positive correlation; ENSO exhibits a correlation with the Baluchistan region on a monthly basis.

2. Study Area

The province of Baluchistan was selected as the study area for this research. It is the largest province in Pakistan with an area of 347,190 square kilometers, which is nearly 44% of Pakistan's total land area, and forms the southwestern part of the country, as shown in Figure 1 [19–21]. Baluchistan is arid and rugged with both plain and mountainous areas. The climate is a hot desert-type with extreme heat and cold [22,23]. Baluchistan's main financial, monetary, economic, and commercial sources of growth are from its coastline on the Arabian Sea and non-renewable resources, such as natural gas, coal, precious stones, gems, zinc, lead, marble, copper, etc. Baluchistan is an area of great importance; it is part of the CPEC.

Two important elements that affect the weather in Pakistan are monsoons and the western disturbance. Light to moderate precipitation in southern parts of the country while moderate to heavy precipitation with heavy snowfall in the northern parts of the country are caused by western disturbances that typically occur in the winter months. Monsoons occur in the summer from June to September in almost all of Pakistan, excluding western Baluchistan, FATA, Chitral, and Gilgit–Baltistan. These monsoon rains are rather heavy by nature and can cause significant flooding if they interact with western disturbances in the northern parts of the country. Tropical storms usually occur in pre-monsoon months from late April to June and then from late September to November; they affect the coastal localities. When there is no precipitation, continental air mainly prevails [6,24,25]. The weather in Baluchistan is mainly affected by western disturbances in the winter and spring months. It is less affected by monsoons during the summer and, to some extent, by tropical storms in coastal areas in the autumn [13,19,20,26,27].

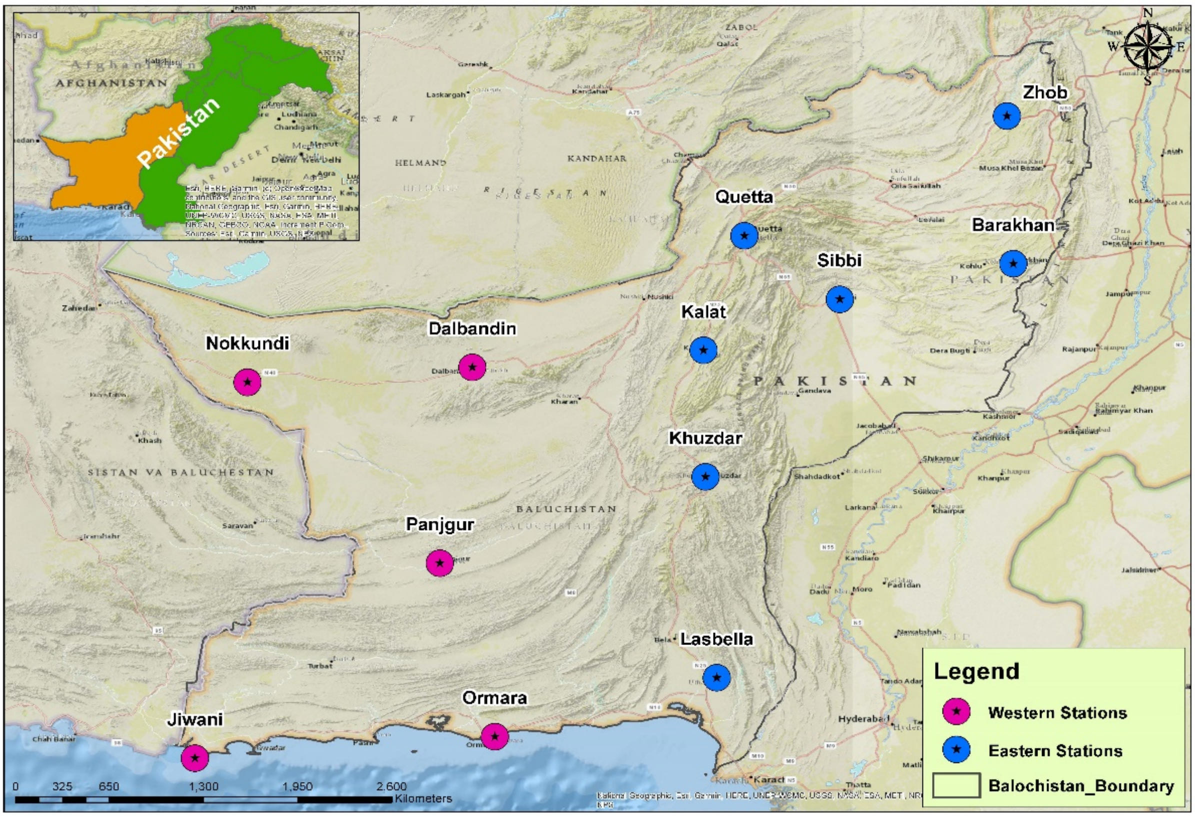

Figure 1. The location map of the selected PMD stations in Baluchistan (figure courtesy of the PMD).

3. Data Collection and Preparation

3.1. Precipitation Data

Monthly precipitation data (in millimeters) were acquired from the Pakistan Meteorological Department (PMD). Thirteen stations in Baluchistan (see Figure 1) were carefully chosen based on accuracy, completeness, and availability of data for the selected study period of 41 years.

The study period constituted forty-one (41) years, from 1977 to 2017, for the 13 stations in Baluchistan. Data collected from the PMD were on a monthly basis (in mm/month) for each weather station, converting them to annual precipitation data for the analysis. The precipitation time series data used in this research study were first assessed for their characteristics (Kurtosis and skewness), distribution types, changes, cycles, outliers, missing values, and homogeneity. The annual time series data of the 13 stations (from the study period) were calculated and the results are shown in Appendix A. The time series normality was conducted by applying tests, namely the Shapiro–Wilk W test, Anderson–Darling, Lilliefors, and the Jarque–Bera test. The normality check tests were performed on the time series and the results are presented in Appendix B. Normality test runs on the annual precipitation time series data showed that the time series data of only four stations, namely Dalbandin, Sibbi, Zhob, and Barakhan, were normally distributed; for the most part, the data were not normally distributed, since the time series data of Dalbandin, Sibbi, Zhob, and Barakhan were normally distributed.

Table 1 shows the average rainfall (monthly and annually) within the study period (from 1997 to 2017) in the 13 stations in Baluchistan.

Table 1. Average precipitation (mm) from 1977 to 2017.

Stations		Winter			Spring/Pre-Monsoon			Monsoon				Post-Monsoon		Annual Precipitation
		Dec.	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	
Barakhan	Eastern	6.5	13.1	21.1	31.3	34.6	24.7	48.2	108.4	84.6	35	9.1	4.9	421.5
Kalat	Eastern	30.3	34.7	37.8	31	11	3.9	6.7	16.3	13.4	4.6	5	5.8	200.5
Khuzdar	Eastern	14.7	16.5	30.9	29.3	16.3	14.1	16.5	51.2	56.6	9.1	6.5	4.3	266.0
Lasbella	Eastern	7.3	4.8	11.4	10.4	7.4	19.7	11.2	53.2	39.3	8.6	5	1.9	180.2
Quetta	Eastern	30.8	53.8	51.7	55.5	26	7.5	4	12.5	11.1	3.1	5.7	8.8	270.5
Sibbi	Eastern	5.6	10.1	17.9	22.3	9.8	6	15.7	38.6	39.1	12.4	3.1	1.6	182.2
Zhob	Eastern	9.2	17.1	26.9	43.5	29.1	14.8	17.7	56.2	44.8	11.1	5.8	5.6	281.8
Dalbandin	Western	9.4	16.8	16	20.5	4.8	1.3	3	3.7	0.7	0.1	2.2	3.1	81.6
Jiwani	Western	20.2	22.9	22.5	14.3	3.7	0.1	7.6	3	2.3	0	1.1	3.6	101.3
Nokkundi	Western	2	7.8	9.6	8.7	2.2	0.2	2	0.7	0.3	0	0.5	0.6	34.6
Ormara	Western	11.8	10.7	10	9.9	1.6	0.2	9.7	11.3	3.8	0.3	2	0.5	71.8
Punjgur	Western	10	12.8	15	15.1	8.3	3.5	5	12.1	7.7	1.7	2.1	1.6	94.9
Region4		12.8	15.2	14.4	12.9	3.6	0.9	6.2	6.5	4.4	0.5	1.6	1.6	67.8
Monthly Avg.		13.7	18.7	22.0	23.7	12.1	7.4	11.8	28.6	24.0	6.7	3.9	3.4	
Seasonal Sum			54.3			43.2			71.1			7.3		

Table 1 shows that for stations in the western parts of Baluchistan, namely Dalbandin, Jiwani, Nokkundi, Ormara, Panjgur, and Pasni, most of the precipitation occurred in the winter season due to the western disturbance. For stations in the Eastern parts of Baluchistan, namely Barakhan, Kalat, Khuzdar, Lasbella, Sibbi, and Zhob, most of the precipitation took place in the monsoon season. Quetta was an exception (most of its precipitation occurred in the winter). Stations close to coastal areas also received scattered rainfall in the post-monsoon season when continental air prevailed. From Table 1, one could see that the eastern part received more precipitation as compared to the western part (on both a monthly and annual basis).

3.2. Climatic Indices

Nine (9) different climatic indices, namely the North Atlantic Oscillation (NAO), Arctic Oscillation (AO), Atlantic Multi-decadal Oscillation (AMO), Indian Ocean Dipole (IOD), Pacific Decadal Oscillation (PDO), El Nino Southern Oscillation (ENSO-MEI), Equatorial Indian Ocean Zonal Wind Index (EQWIN), and ENSO Modoki Index (EMI), known to affect the precipitation in the study area through teleconnections, were considered [15,18,28]. However, the influences of climate indices, namely Equatorial Indian Ocean Zonal Wind Index (EQWIN) and ENSO Modoki Index (EMI), have never been studied in Baluchistan [13]. One of the novelties of this research involves the study of these indices and their significant influences (by using a combination of the PMK and Pearson's correlation).

4. Methodology

Trend analyses using Mann–Kendall tests were carried out on a monthly basis for the duration of the study at each of the 13 stations. The January periods (from 1977 to 2017) were analyzed for trends (and so on for the other months). The stations and months that had significant and noteworthy trends were considered for further analyses. The association between precipitation and climate indices was determined by Pearson's correlation test, whereas the influences of climate indices (influencing variables) on trends in precipitation were examined by the partial Mann–Kendall test. Finally, using the combined approach, for those stations having significant and noteworthy precipitation trends, the influencing variables (climate indices) were short-listed. These significant correlations with precipitation had weak, moderate, and strong influences on precipitation.

4.1. Mann–Kendall for Trend Detection

The Mann–Kendall (MK) statistical test was largely used in identifying trends in climate variables [14,26,28–34]. The reasons for adopting the Mann–Kendall test are that it is strong and insensitive to data with gaps and best for data that are not normally distributed. The MK test was not sensitive to sudden breaks in uneven data. The nonparametric MK test is a strong method used to identify monotonic trends in precipitation data where the data are skewed and/or consistently increase or decrease in a time series. The MK test is not suitable when there are recurring trends.

In the MK test, if $(X_1, X_2, \ldots, Xn)$ are samples of n independent and identically distributed random variables of the rainfall data, then the Mann–Kendall statistic S_x of the series x is given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(X_j - X_i\right)$$

$$sgn\left(X_j - X_i\right) = \begin{cases} +1 & \left(X_j - X_i\right) > 0 \\ 0 \text{ if } & \left(X_j - X_i\right) = 0 \\ -1 & \left(X_j - X_i\right) < 0 \end{cases}$$

where i and j are the ranks of observation of the x_i and x_j of the time series. The variance associated with S_x is given as

$$Var = \frac{n(n-1)(2n+5) - \sum_{i=1}^{g} t_i(t_i - 1)(2t_i + 5)}{18}$$

where g is the tied rank group and t is the tie in the group. For a sample size of $n > 10$ or larger, the MK statistic Z_{mk} is computed by

$$Z_{mk} = \begin{cases} \frac{S_x - 1}{\sigma} & for\ S_x > 0 \\ \frac{S_x + 1}{\sigma} & for\ S_x < 0 \\ 0 & for\ S_x = 0 \end{cases}$$

Positive Z_{mk} values showed increasing trends, while negative Z_{mk} values reflected decreasing trends. If $|Z_m k|$ is greater than $Z_{1\text{-}\alpha/2}$ for the chosen value of the significance level (α), then the trends are considered significant, or when the p-value is smaller than the significance level (α), the null hypothesis (Ho) of no trend is rejected in favor of an alternative hypothesis (Ha), and the trend is considered significant in the time series. The $Z_{1\text{-}\alpha/2}$ and p-value were obtained from the standard normal distribution table (see Appendix C).

4.2. Pearson's Correlation for Finding Linear Associations

Pearson's correlation, based on the method of covariance, is one of the best methods that measures the strength of linear associations between two variables. It provides information about the magnitude and direction of the association. The direction can be positive or negative; the magnitude ranges between +1 and −1, with +1 being a perfect positive correlation and −1 being a perfect negative correlation. A value of zero indicates that there is no linear correlation. It should be kept in mind that the existence of a significant correlation is not causation for the variables. In other words, association does not mean causation; a significant regression coefficient might be the reason why a simple association is interpreted cautiously. The significance of the correlation is determined by the Student *t*-test. The *t*-test establishes whether there is evidence that a significant correlation is present between the variables [35]. The *t*-test is given by

$$t = \frac{r \times \sqrt{n-2}}{\sqrt{1-r^2}}$$

where r and n are the correlation coefficient and the number of observations in the data series, respectively. For precipitation and climatic index being the two variables, correlation is considered significant for the desired value of the significance level (α) with an $n-2$ degree of freedom if $|t|$ is greater than the critical $t_{1\text{-}\alpha/2}$ or if the *p*-value is smaller than the significance level (α). The null hypothesis of no correlation is rejected in favor of the alternative hypothesis—that there is a significant correlation between the precipitation and climatic indices. The $t_{1\text{-}\alpha/2}$ and *p*-value were obtained from the standard normal distribution table (attached as Appendix C).

4.3. Theil–Sen (TS) Slope

The Theil–Sen slope was applied to find the magnitude of the precipitation trend. TS is the most widely used, nonparametric, statistical technique to assess linear trends. It is more robust because it is insensitive to the effect of outliers and performs better even for skewed and heteroskedastic data [36]. According to the TS method, the overall slope S^* is the median of N values of slope S, and is given by

$$S^* = \frac{S_N + 1}{2} \; If \; N \; is \; odd$$

$$S^* = \frac{\frac{S_N}{2} + \frac{S_N + 2}{2}}{2} \; If \; N \; is \; even$$

where S is the slope between any two values of a time series x. For a time series x having n observations, there are a possible $N = n \times (n-1)/2$ values of S that can be calculated using

$$S = \frac{x_k - x_j}{k - j} \quad Where \; k \neq j$$

4.4. Partial Mann–Kendall for Examining the Influence of Climatic Indices on Precipitation Trends

The climatic indices were taken as covariates (influencing variables), whereas precipitation was taken as the dependent variable. The effect of climatic indices on precipitation was determined by applying the PMK and Pearson correlation. The influences of large-scale climatic and atmospheric indices (influencing variables), such as NAO, AO, AMO, IOD, PDO, ENSO-MEI, EQWIN, EMI, and outgoing longwave radiation (OLR) on the precipitation time series, were examined by adopting the partial Mann–Kendall (PMK) test in this study. Studies, such as [36–39], also used the PMK in their analyses.

The PMK is one of the best one-step procedures that conducts the adjustments for covariates (influencing variables) and trend testing simultaneously. In the PMK, the effects of the explanatory variables were studied on the response variable and the influence was calculated using the conditional mean and the conditional variance of the response variable. As shown in [37], the test statistic for the response variable y, with its covariate x being the explanatory variable is given by

$$\text{PMK} = \frac{S_y - \hat{\rho} S_x}{\sqrt{(1-\hat{\rho})n(n-1)(2n+5)/18}} \tag{1}$$

where S_y is the Mann–Kendall statistic of the response variable, S_x is the Mann–Kendall statistic of the explanatory variable, and $\hat{\rho}$ denotes the conditional correlation between the MK statistics, S_x and S_y. The PMK statistic is normally distributed with a mean of 0 and a standard deviation of 1 [37].

5. Results and Discussion

Increasing or decreasing trends were observed when the univariate Mann–Kendall test was run on the precipitation time series data. The climatic indices were taken as co-variates (influencing variables) whereas precipitation was taken as the dependent variable. The effect of climatic indices on precipitation was determined by applying the PMK and Pearson's correlation.

5.1. Trends in Precipitations

Monotonic trends in monthly precipitation from 1977 to 2017 were found through the Mann–Kendall (MK) test at individual stations. Table 2 shows that out of 15 statistically significant trends, 11 were decreasing trends, whereas 4 (highlighted) were increasing trends. Increasing trends were found in Barakhan (June), Quetta (June and September), and Sibbi (June) only; this clearly indicates that decreasing precipitation trends dominated most of the stations in Baluchistan. Many studies, including the most recent one carried out by Naz et al. in 2020, confirmed this finding [20]. Global warming and consequent climate changes appeared to be responsible for the variations in the precipitation trend [11,19]. Variability in precipitation trends (due to climate change) was one of the major challenges faced by Pakistan and the province of Baluchistan (where the situation was already worse). This scenario led to recurring droughts of different spans and intensities in the last few decades. The drought of 1998–2002 was one of the worst in the last 50 years; it caused famine in part of the study area [1,19–21]. Kalat, Lasbella, Nokkundi, and Pasni showed no statistically significant trends in precipitation (at a 5% significance level) and, hence, were ignored for further analyses.

Table 2. Monthly significant increasing (decreasing) trends in precipitation—individual stations.

Stations	Parameters	January	February	March	April	May	June	July	August	September	October	November	December
Barakhan	S	−177	−70	−144	−57	−1	175	−76	44	−79	7	−211	−74
	P	**4.62%**	43.14%	10.57%	52.20%	99.10%	**4.93%**	39.33%	62.12%	37.49%	93.32%	**1.07%**	38.76%
	TS	−0.205 *	−0.206	−0.478	−0.187	0.000	0.832 *	−0.767	0.354	−0.291	0.000	0.000	0.000
Dalbandin	S	−132	−43	−79	−53	−98	−21	−42	−67	13	−24	−91	−208
	P	13.74%	62.70%	37.29%	54.73%	22.36%	76.83%	49.35%	27.46%	74.52%	71.94%	23.49%	**1.64%**
	TS	−0.240	−0.027	−0.113	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−0.051
Jiwani	S	−13	−158	−72	−93	−30	−59	−34	−58	0	−32	−72	−245
	P	88.23%	6.31%	39.71%	19.20%	20.49%	30.99%	57.93%	41.59%	0.00%	48.30%	24.04%	**0.37%**
	TS	0.000	−0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−0.074
Kalat	S	−43	47	28	−35	23	68	−167	−68	9	−68	66	−114
	P	62.89%	59.72%	75.22%	69.12%	78.48%	39.87%	5.41%	43.02%	89.95%	28.97%	42.94%	18.86%
	TS	−0.079	0.130	0.004	0.000	0.000	0.000	−0.117	0.000	0.000	0.000	0.000	−0.049
Khuzdar	S	−97	−67	28	−47	28	31	−20	−59	30	−93	−151	−178
	P	27.45%	45.12%	75.27%	59.65%	75.21%	72.56%	82.22%	50.75%	73.06%	21.50%	6.45%	**4.01%**
	TS	−0.117	−0.242	0.092	−0.011	0.000	0.000	−0.067	−0.380	0.000	0.000	0.000	−0.094
Lasbella	S	9	−120	58	41	133	78	−92	−60	105	−84	−90	−57
	P	91.68%	16.84%	50.54%	63.79%	13.09%	37.58%	29.86%	49.69%	16.15%	23.88%	19.32%	39.36%
	TS	0.000	−0.046	0.000	0.000	0.292	0.004	−0.225	−0.150	0.000	0.000	0.000	0.000
Nokkundi	S	62	8	−2	12	20	59	−48	−63	0	39	−26	−72
	P	47.94%	92.72%	98.19%	87.98%	77.89%	24.13%	34.06%	11.52%	0.00%	52.48%	68.56%	37.15%
	TS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2. *Cont.*

Stations	Parameters	January	February	March	April	May	June	July	August	September	October	November	December
Ormara	S	−19	−28	−73	−67	−205	108	82	66	5	−407	−20	−19
	P	82.81%	74.38%	37.14%	31.60%	**0.63%**	7.82%	30.15%	35.46%	92.09%	**0.01%**	69.13%	82.32%
	TS	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	−0.005	0.000	0.000
Panjgur	S	−28	−93	−56	−32	135	18	−195	−78	−5	−76	−90	−176
	P	75.17%	29.40%	52.60%	70.43%	8.89%	80.07%	**2.28%**	31.75%	93.79%	13.13%	17.80%	**3.51%**
	TS	0.000	−0.131	−0.019	0.000	0.000	0.000	−0.083	0.000	0.000	0.000	0.000	0.000
Pasni	S	−52	−64	−60	0	−35	15	10	−116	6	−50	49	−91
	P	55.68%	46.03%	48.35%	100.00%	38.15%	81.53%	89.61%	12.19%	89.54%	27.30%	42.43%	28.44%
	TS	−0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Quetta	S	−224	−44	−157	130	165	206	−33	−12	153	8	76	−169
	P	**1.19%**	62.11%	7.78%	14.38%	6.07%	**1.26%**	70.15%	88.99%	**3.14%**	91.50%	37.77%	5.74%
	TS	−1.223 *	−0.265	−0.966	0.200	0.019	0.000	0.000	0.000	0.001	0.000	0.000	−0.543
Sibbi	S	−69	23	−91	−42	154	186	22	21	153	−57	−61	−63
	P	43.55%	79.55%	30.66%	62.80%	6.78%	**2.59%**	80.46%	81.35%	6.70%	32.66%	43.44%	45.50%
	TS	−0.031	0.000	−0.185	0.000	0.000	0.000	0.042	0.069	0.000	0.000	0.000	0.000
Zhob	S	−201	−19	−132	−39	38	161	56	−122	77	−38	−39	−160
	P	**2.39%**	83.08%	13.81%	66.12%	66.85%	7.04%	52.93%	17.06%	38.20%	61.98%	64.03%	6.63%
	TS	−0.417 *	−0.029	−0.655	−0.078	0.044	0.250	0.264	−0.559	0.029	0.000	0.000	−0.056

The numbers in bold represent significant correlations at a 5% confidence level. * Shows the noteworthy Theil–Sen (TS) slope. S is the Mann–Kendall statistic, p is the p-value of the null hypothesis (Ho) of no trend at a 5% significance, and TS is the Theil–Sen slope.

The Theil–Sen (TS) slope was also calculated (shown in Table 2). The Theil–Sen slope with (*) indicates trends in Barakhan (January and June), Khuzdar (December), Quetta (January), and Zhob (January), whereas all others are almost negligible and, thus, can be ignored. The graphs showing the trend in precipitation for each station, (against time) for January and June are presented in Appendix E. The trend equations and trend line in dotted are also mentioned on each graph. It can be inferred from the graphs that the decrement (increment) trend slopes (for January and June, for which the MK and TS report significant trends (i.e., p-value < 5%)), are much higher as compare to other months.

5.2. Linear Association of Climatic Indices with Precipitation

Pearson's correlation was performed between the climate indices and precipitation data of the individual PMD stations to check the association between the dependent and independent variables. For the 41-year time series data, a correlation coefficient value of 0.316 (−0.316) or higher (lower) is considered significant for a two-tailed test at a 5% significance level (attached as Appendix D). Only those stations and months were selected that had significant trends in precipitation, as shown in Table 2. The results of the correlation between the precipitation (dependent variable) and climatic indices (independent variables) are shown in Table 3.

Table 3. Correlation of precipitation at individual stations with climatic indices.

PMD Stations	Month	NAO	AO	IOD	PDO	ENSO-MEI	EQWIN	EMI-MODOKI	OLR
Barakhan	January	−15.83%	**−0.02%**	**−1.22%**	**−1.57%**	**1.77%**	−14.05%	21.46%	−44.79%
	June	−6.05%	−6.59%	**4.74%**	31.85%	6.40%	**3.94%**	**−0.34%**	**−2.81%**
	November	11.61%	25.03%	40.10%	**1.08%**	37.93%	59.39%	−42.18%	**−3.97%**
Dalbandin	December	−7.74%	5.24%	8.22%	−5.84%	14.75%	39.38%	−12.64%	26.08%
Jiwani	December	−27.97%	**−2.45%**	8.93%	**0.86%**	26.66%	55.29%	−34.32%	25.29%
Khuzdar	December	**−0.17%**	12.84%	9.50%	−18.98%	22.22%	30.97%	−20.08%	14.76%
Ormara	May	14.77%	**1.18%**	−15.80%	41.16%	24.07%	**−4.80%**	−26.83%	14.05%
	October	−13.33%	**−2.67%**	−7.96%	14.66%	9.79%	5.90%	−6.90%	−34.94%
Panjgur	July	6.10%	−15.01%	**2.24%**	**1.52%**	−24.26%	21.98%	11.83%	6.50%
	December	14.52%	19.09%	8.45%	−5.95%	24.03%	37.27%	−21.87%	12.53%
Quetta	January	**−0.93%**	14.93%	**3.70%**	−12.46%	**3.66%**	13.20%	−23.98%	−19.27%
	June	−17.37%	−11.43%	16.90%	7.14%	**−3.48%**	27.02%	17.05%	−21.23%
	September	−11.23%	9.12%	33.63%	−33.02%	**0.48%**	25.04%	**1.42%**	15.25%
Sibbi	June	−24.40%	−12.08%	20.67%	**2.41%**	**−1.29%**	31.57%	12.99%	−17.16%
Zhob	January	−28.68%	−18.96%	11.76%	−11.04%	14.91%	23.30%	−20.99%	−9.06%

The significant correlations are shown in bold font for confidence levels of 0.05 (5%).

We mentioned above that the precipitation time series data from the Barakhan, Khuzdar, Quetta, and Zhob stations showed noteworthy trends; therefore, only these stations were considered. The influences of climatic indices determined through the correlation analyses are shown in Table 4.

Table 4. Correlation of precipitation of climatic indices (individual stations) with significant trends and noteworthy Theil–Sen slopes.

PMD Stations	Month	NAO	AO	IOD	PDO	ENSO-MEI	EQWIN	EMI-MODOKI	OLR
Barakhan	January	−15.83%	**−0.02%**	**−1.22%**	**−1.57%**	**1.77%**	−14.05%	21.46%	−44.79%
	June	−6.05%	−6.59%	**4.74%**	31.85%	6.40%	**3.94%**	**−0.34%**	**−2.81%**
Khuzdar	December	**−0.17%**	12.84%	9.50%	−18.98%	22.22%	30.97%	−20.08%	14.76%
Quetta	January	**−0.93%**	14.93%	**3.70%**	−12.46%	**3.66%**	13.20%	−23.98%	−19.27%
Zhob	January	−28.68%	−18.96%	11.76%	−11.04%	14.91%	23.30%	−20.99%	−9.06%

The significant correlations are shown in bold font for confidence levels of 0.05 (5%).

Several studies have emphasized that ENSO and NAO affect the weather in Pakistan (regionally and locally) [40]. For example, Yadav et al. [41] suggested that the effect of ENSO has increased as compared to NAO. Rashid [42] studied the impact of ENSO and stated that ENSO had a negative effect on the winter rainfall in Pakistan. The rainfall in the winter in Pakistan shows below normal behavior under the influence of the ENSO (-ve) phase (i.e., La Niña condition). Researchers [43,44] found that ENSO does not have any significant adverse impact on the August rainfall over Pakistan.

The correlation between precipitation and climatic indices through Pearson's correlation was carried out by Iqbal and Athar [19]. Four confidence level (CL) thresholds were considered in that study. Marginal CL (CL < 80%), moderate CL (80% ≤ CL < 90%), strong CL (90% ≤ CL < 95%), and very strong CL (CL ≥ 95%). Based on these confidence levels, the researchers defined whether the climate indices correlated with precipitation on monthly or annual timescales. Iqbal and Athar [19] reported that NAO showed a correlation with Baluchistan, a positive phase of IOD had a positive correlation, a positive (negative) phase of AO showed a correlation, PDO showed a positive correlation, and ENSO exhibited a correlation in Baluchistan, but on a monthly basis. Iqbal and Athar's [19] study did not define the specific months; this was a clear research gap in their study.

Table 4 shows that NAO, AO, IOD, PDO, and ENSO-MEI are correlated with December and January precipitation whereas EQWIN, EMI, and OLR are correlated with June precipitation. This confirms the findings in the previous studies.

5.3. Influence of Climatic and Atmospheric Indices on Precipitation Trends

Pearson's correlation only measures the strength of the linear association between two variables. For a non-linear series, if the correlation report series are insignificantly correlated, it simply means that there is no linear correlation between the two variables and there may be a non-linear relationship. Precipitation and climate are greatly non-linear in nature and can upswing to the butterfly effect [45]. Hence, the use of linear correlation alone to study the effects of climatic indices on precipitation may not yield reasonable results. Another approach to studying the influence of climatic indices on precipitation is to study the variations in precipitation trends in the presence of climatic indices, which are the covariates. Libisellar [37] established the trends in precipitation in the presence of the relevant covariates.

In this study, the variations in precipitations trends in the presence of influencing variables, such as NAO, AO, AMO, IOD, PDO, ENSO-MEI, EMI, EQWIN, and OLR were determined through the PMK test, on monthly precipitation and at individual station levels. The influences of the response variables for this study (through the PMK test) are classified into insignificant, weak, moderate, and strong, as described in Table 5.

Table 5. Classifications of influence types.

S. No	Condition	Influence Type
1	MK and PMK show no significant trends.	Insignificant
2	MK shows no significant trend and PMK shows a significant trend or vice versa; OR both MK and PMK show significant trends; the addition of the influencing variable changes the MK statistics by up to 10%.	Weak
3	MK shows no significant trend and PMK shows a significant trend or vice versa; OR both MK and PMK show significant trends; the addition of the influencing variable changes the MK statistics from 10% to 20%.	Moderate
4	MK shows no significant trend and PMK shows a significant trend or vice versa; OR both MK and PMK show significant trends; the addition of the influencing variable changes the MK statistics by greater than 20%.	Strong

The PMK test is run on the monthly precipitation time series, with the response variable and the climatic indices being explanatory variables, including NAO, AO, AMO, IOD, PDO, ENSO-MEI, EMI, EQWIN, and OLR. The statistically significant trends in the presence of the relevant influencing variables, along with their influence types, are tabulated in Table 6.

Table 6. Influence of the climatic index on precipitation trends.

Climatic Index	Months	Stations	Mann–Kendall			Partial Mann–Kendall with Covariate			% Change in MK Statistics due to NAO as Covariate	Influence Type
			p-Value	MK Statistics	Trend Type	*p*-Value	PMK Statistics	Trend Type		
NAO	January	Barakhan	0.0462	−177	Decreasing	0.0480	−174.1	Decreasing	1.64%	Weak
		Quetta	0.0119	−224	Decreasing	0.0121	−223.4	Decreasing	0.27%	Weak
		Zhob	0.0239	−201	Decreasing	0.0245	−196.8	Decreasing	2.09%	Weak
	June	Barakhan	0.0493	175	Increasing	0.0576	168.8	Increasing	3.54%	Weak
	December	Khuzdar	0.0401	−178	Decreasing	0.0574	−162	Decreasing	8.99%	Weak
AO	January	Barakhan	0.0462	−177	Decreasing	0.0397	−179	Decreasing	1.13%	Weak
		Quetta	0.0119	−224	Decreasing	0.0113	−225.4	Decreasing	0.63%	Weak
		Zhob	0.0239	−201	Decreasing	0.0268	−196.1	Decreasing	2.44%	Weak
	June	Barakhan	0.0493	175	Increasing	0.0457	176.5	Increasing	0.86%	Weak
	December	Khuzdar	0.0401	−178	Decreasing	0.0215	−179.3	Decreasing	0.73%	Weak
IOD	January	Barakhan	0.0462	−177	Decreasing	0.0338	−188	Decreasing	6.21%	Weak
		Quetta	0.0119	−224	Decreasing	0.0086	−233.4	Decreasing	4.20%	Weak
		Zhob	0.0239	−201	Decreasing	0.0124	−221	Decreasing	9.95%	Weak
	June	Barakhan	0.0493	175	Increasing	0.0485	175.6	Increasing	0.34%	Weak
	December	Khuzdar	0.0401	−178	Decreasing	0.0205	−197.5	Decreasing	10.96%	Moderate
PDO	January	Barakhan	0.0462	−177	Decreasing	0.0325	−185.9	Decreasing	5.03%	Weak
		Quetta	0.0119	−224	Decreasing	0.0097	−228.8	Decreasing	2.14%	Weak
		Zhob	0.0239	−201	Decreasing	0.0219	−203.5	Decreasing	1.24%	Weak
	June	Barakhan	0.0493	175	Increasing	0.0357	183.4	Increasing	4.80%	Weak
	December	Khuzdar	0.0401	−178	Decreasing	0.0304	−182.7	Decreasing	2.64%	Weak
ENSO-MEI	January	Barakhan	0.0462	−177	Decreasing	0.0437	−182.5	Decreasing	3.11%	Weak
		Quetta	0.0119	−224	Decreasing	0.0161	−213	Decreasing	4.91%	Weak
		Zhob	0.0239	−201	Decreasing	0.0362	−183.7	Decreasing	8.61%	Weak
	June	Barakhan	0.0493	175	Increasing	0.0410	181	Increasing	3.43%	Weak
	December	Khuzdar	0.0401	−178	Decreasing	0.0751	−150.5	Decreasing	15.45%	Moderate
EMI	January	Barakhan	0.0416	−181	Decreasing	0.1119	−139.4	Decreasing	−22.95%	Strong
		Quetta	0.0118	−224	Decreasing	0.1035	−136.7	Decreasing	−38.95%	Strong
		Zhob	0.0238	−201	Decreasing	0.1797	−112.4	Decreasing	−44.07%	Strong
	June	Barakhan	0.0493	175	Increasing	0.1075	140.8	Increasing	−19.49%	Moderate
	December	Khuzdar	0.0400	−178	Decreasing	0.1190	−133.0	Decreasing	−25.27%	Strong
EQWIN	January	Barakhan	0.0416	−181	Decreasing	0.0708	−158.0	Decreasing	−12.68%	Moderate
		Quetta	0.0118	−224	Decreasing	0.0210	−202.5	Decreasing	−9.56%	Weak
		Zhob	0.0238	−201	Decreasing	0.0521	−166.9	Decreasing	−16.95%	Moderate
	June	Barakhan	0.0493	175	Increasing	0.0080	210.8	Increasing	20.50%	Strong
	December	Khuzdar	0.0400	−178	Decreasing	0.3695	−68.1	Decreasing	−61.71%	Strong
OLR	January	Barakhan	0.0461	−177	Decreasing	0.0425	−179.8	Decreasing	1.61%	Weak
		Quetta	0.0118	−224	Decreasing	0.0383	−177.1	Decreasing	−20.93%	Strong
		Zhob	0.0238	−201	Decreasing	0.0769	−154.6	Decreasing	−23.04%	Strong
	June	Barakhan	0.0493	175	Increasing	0.0526	171.2	Increasing	−2.17%	Weak
	December	Khuzdar	0.0400	−178	Decreasing	0.0497	−166.5	Decreasing	−6.42%	Weak

The influence on precipitation using the PMK of only those stations, for instance, Barakhan, Khuzdar, Quetta, Zhob, are shown in Table 6, which have significant trends. Table 6 shows that the trends are significant in the months of January, June, and December. The influence of climate indices is weak in the winter months (December and January) whereas it is moderate to strong in the monsoon months (e.g., June). The above findings strengthen the findings of Yadav et al. [41], who suggested that the influence of NAO is weakened during the winter as compared to the influence of ENSO during the summer in this region. The study suggests that the influence of EMI, which is another variation of ENSO, is stronger than ENSO-MEI. Further, the influence of EQWIN is stronger than IOD, which is another climate index in the Indian Ocean associated with monsoons. Aamir and Hassan [13] suggested that the EMI and EQWIN have a significant correlation with Barakhan, Khuzdar, Quetta, and Zhob stations than ENSO-MEI and IOD.

5.4. Analysis of PMK and Correlation Depicting the Influences of Climatic Indices—A Combined Approach

The results obtained in Section 5.2 (Table 4) and Section 5.3 (Table 6) were analyzed (combined). The results obtained by taking the intersections are shown in Table 7, showing the significant correlations of climate indices with the precipitation of those stations had significant and noteworthy trends, along with their influences (classified as weak, moderate, or strong). Table 7 shows that NAO, AO, IOD, PDO, and ENSO-MEI were significantly correlated but had a weak influence on precipitation in December and January. Similarly, IOD, EMI, EQWIN, and OLR were significantly correlated but had a moderate to strong influence on precipitation in June.

Table 7. Influence of climatic index on precipitation trends.

Variables	Months	Stations	Mann–Kendall		Partial Mann–Kendall with Covariate		% Change in MK Statistics Due to Addition of Covariate	Influence Type as per PMK	Pearson Correlation
			p-Value	MK Statistics	*p*-Value	PMK Statistics			
NAO	January	Quetta	0.0119	−224	0.0121	−223.4	0.27%	Weak	−0.93%
AO		Barakhan	0.0462	−177	0.0397	−179	1.13%	Weak	−0.02%
IOD		Barakhan	0.0462	−177	0.0338	−188	6.21%	Weak	−1.22%
		Quetta	0.0119	−224	0.0086	−233.4	4.20%	Weak	3.70%
PDO		Barakhan	0.0462	−177	0.0325	−185.9	5.03%	Weak	−1.57%
ENSO-MEI		Barakhan	0.0462	−177	0.0437	−182.5	3.11%	Weak	1.77%
		Quetta	0.0119	−224	0.0161	−213	4.91%	Weak	3.66%
IOD	June	Barakhan	0.0493	175	0.0485	175.6	0.34%	Weak	4.74%
EMI		Barakhan	0.0493	175	0.1076	140.9	−19.49%	Moderate	−0.34%
EQWIN		Barakhan	0.0493	175	0.0080	210.9	20.50%	Strong	3.94%
OLR		Barakhan	0.0493	175	0.0527	171.2	−2.17%	Weak	−2.81%
NAO	December	Khuzdar	0.0401	−178	0.0574	−162	8.99%	Weak	−0.17%

5.4.1. Weak Effect of -NAO/-AO

Table 7 shows that the negative phase of the NAO had a weak influence on the precipitation in the eastern region stations whereas stations in the western parts remained unaffected. During the negative phase of NAO, the Atlantic jet stream and storm track situated further south gathered moisture from the Mediterranean Sea crossing this region. The embedded western disturbances in the westerlies are responsible for the precipitation under favorable conditions. Ahmed [27] found that the positive (negative) phase of NAO strengthens (weakens) winter–spring precipitation in the northern parts of Pakistan above 31.5° in latitude, as the Atlantic jet stream and storm track situated further north are responsible for the precipitation (whereas Baluchistan is mostly located below 31.5° in latitude). Athar [15] found that NAO was correlated with precipitation in Baluchistan (without mentioning whether the correlation was positive or negative). Yadav et al. [41] suggested that winter precipitation in the western Indian region was influenced by positive NAO/AO. The positive/negative pressure anomaly intensifies the Asian westerly jet stream over North Africa and the Middle East extending up to northwest India. The jet stream intensifies the western disturbances and is responsible for increased precipitation over northern Pakistan and northwest India. The effect of AO, either positive or negative, is insignificant in this region. This study shows that the weak effect of NAO/AO is also extended to the eastern parts of Baluchistan.

5.4.2. Weak Effect of ENSO-MEI/IOD/AMO/PDO

The negative phase of ENSO-MEI (La Niña) has a moderate effect on the winter precipitation of this region. This is in line with the findings from previous studies on this region [19,44,45]. Khan suggested that during negative ENSO episodes, cooler than normal ocean temperatures in the equatorial Central Pacific act to restrain the formation of rain-producing clouds in the region. Mid-latitude depressions are inclined to be weaker than normal. La Niña episodes include large-scale changes in the atmospheric winds across the tropical Pacific, including increased winds from the east across the eastern Pacific in the lower atmosphere and greater winds from the west over the eastern tropical Pacific in the upper atmosphere [46,47]. These conditions explain an increased strength of the equatorial Walker circulation. Winter season rainfall activity over Pakistan is suppressed under similar La Niña conditions during the fall. However, if the La Niña event declines and its intensity becomes weak during the winter relative to the previous quarter (fall), i.e., an increase in the sea surface temperature, then rainfall activity over Pakistan tends to lie between normal to greater than normal. Similarly, Chakraborty [48] suggests that the interannual variation of moisture flux is strongly modified by positive IOD and positive ENSO events, which confirms the findings of this study. During these events, the moisture transport from the Red Sea toward the mountainous region of the Asir province of Saudi Arabia increases. As a result, rain activity from November to April increases. The negative phase of PDO and the positive phase of AMO have moderate effects on the winter precipitation of this region. AMO and PDO are indices showing the multi-decadal variations in SST in the North Atlantic and North Pacific oceans and are negative phase-locked. The negative phase of PDO enhances the effect of cold ENSO (La Niña), whereas the positive phase of AMO weakens the effect of NAO/AO but modestly affects the warming of the Indian Ocean. Ashok [39] suggested that the negative phase of PDO and the positive phase of AMO have moderate effects on the winter precipitation of this region.

5.4.3. Significant Effects of EQWIN and EMI

No studies were conducted to find the impacts of EQWIN and EMI, especially in this region [13], but their effects were examined in this study for the first time. Table 7 shows that EQWIN, which is the index for the EQUINOO in the Indian ocean, has a significant positive correlation with the precipitation in eastern parts of Baluchistan, whereas the positive phase of EMI, an index of the large-scale tripole anomalous conditions in the equatorial Pacific Ocean, also has a significant positive correlation in this region. This study confirmed the findings of Ashok [39], who suggested that relatively higher rainfall was observed over the Indian subcontinent during the El Nino MODOKI season as compared to the El Nino dry periods.

6. Conclusions

The greater portion of Baluchistan's precipitation takes place in the summer months. Decreasing trends in precipitation were observed in the winter and spring months (in November, December, January, and May) when the time series data were analyzed from 1977 to 2017 using the Mann–Kendall test, confirming that Baluchistan has received less precipitation in the past few decades. The eastern part of Baluchistan receives more precipitation than the western part. The influence of climate indices on precipitation was found to be significant in the eastern part whereas no significant influence was found in the western part of Baluchistan. It was observed that the influences of climate indices are weak in the winter months and moderate to strong in the monsoon months, specifically in the eastern part of Baluchistan. It was observed that NAO, AO, IOD, PDO, and ENSO-MEI have significant correlations but weak influences on the stations in the eastern part of Baluchistan in the winter months of December and January. It was also observed that MEI, EQWIN, and OLR have significant correlations and strong to moderate influences on the precipitation trends in the monsoon months (e.g., June) in stations in the eastern part of Baluchistan. This confirms the findings of a previous study (with respect to ENSO and NAO) that, in recent years, ENSO has affected the climate more than AO/NAO, and the latter are losing control in determining the climate variabilities in the winter months, regarding northwestern precipitation in India, which is adjacent to Pakistan. The study also shows that MEI and EQWIN are significantly correlated and have a strong influence; thus, they are more relevant indices than IOD and ENSO-MEI for assessing the influence on precipitation over this region.

Author Contributions: Conceptualization, methodology, and software E.A.; Formal analysis A.K.; Review and editing, M.A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors thank the anonymous reviewers for their valuable comments. Muhammad Atiq Ur Rehman Tariq have provided significant inputs for the supervisory of the research. Helped in finalizing the visualization of results and played a major role in the revision of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Linear regression on the annual time series.

Sr. No.	Stations	Mean	Standard Deviation	Kurtosis	Skewness
1	Barakhan	421.376	140.047	0.769	0.455
2	Dalbandin	82.085	48.085	−0.214	0.585
3	Jiwani	99.795	88.784	2.266	1.519
4	Kalat	200.413	170.917	10.050	2.612
5	Khuzdar	265.875	118.215	1.147	0.994
6	Lasbella	180.154	115.972	1.134	1.137
7	Nokkundi	34.354	37.975	5.998	2.202
8	Ormara	70.928	92.889	11.605	3.031
9	Panjgur	94.884	56.881	3.950	1.641
10	Pasni	100.098	81.228	0.902	1.034
11	Quetta	270.502	152.860	9.365	2.542
12	Sibbi	182.203	89.558	−0.724	0.310
13	Zhob	281.859	92.734	−0.101	0.193

Appendix B

Table A2. Normality tests on the annual time series.

S. No	Stations	Shapiro–Wilk	Anderson–Darling	Lilliefors	Jarque–Bera
1	Dalbandin	passed	passed	passed	passed
2	Jiwani	failed	failed	failed	failed
3	Kalat	failed	failed	failed	failed
4	Lasbella	failed	failed	failed	failed
5	Nokkundi	failed	failed	failed	failed
6	Ormara	failed	failed	failed	failed
7	Panjgur	failed	failed	failed	failed
8	Pasni	failed	failed	failed	failed
9	Quetta	failed	failed	failed	failed
10	Sibbi	passed	passed	passed	passed
11	Zhob	passed	passed	passed	passed
12	Khuzdar	failed	failed	failed	failed
13	Barakhan	passed	passed	passed	passed

Appendix C

Table A3. The standard normal *t*-distribution table.

Cum. Prob	***t* 0.50**	***t* 0.75**	***t* 0.80**	***t* 0.85**	***t* 0.90**	***t* 0.95**	***t* 0.975**	***t* 0.99**	***t* 0.995**	***t* 0.999**	***t* 0.9995**
One-Tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
Two-Tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Appendix D

Table A4. Critical values for Pearson's r.

Critical Values for Pearson's r: (For a Two-Tailed Test:)				
df:	**0.1**	**0.05**	**0.02**	**0.01**
1	0.988	0.997	0.9995	0.9999
2	0.9	0.95	0.98	0.99
3	0.805	0.878	0.934	0.959
4	0.729	0.811	0.882	0.917
5	0.669	0.754	0.833	0.874
6	0.622	0.707	0.789	0.834
7	0.582	0.666	0.75	0.798
8	0.549	0.632	0.716	0.765
9	0.521	0.602	0.685	0.735
10	0.497	0.576	0.658	0.708
11	0.476	0.553	0.634	0.684
12	0.458	0.532	0.612	0.661
13	0.441	0.514	0.592	0.641
14	0.426	0.497	0.574	0.623
15	0.412	0.482	0.558	0.606
16	0.4	0.468	0.542	0.59
17	0.389	0.456	0.528	0.575
18	0.378	0.444	0.516	0.561
19	0.369	0.433	0.503	0.549
20	0.36	0.423	0.492	0.537
21	0.352	0.413	0.482	0.526
22	0.344	0.404	0.472	0.515
23	0.337	0.396	0.462	0.505
24	0.33	0.388	0.453	0.496
25	0.323	0.381	0.445	0.487
26	0.317	0.374	0.437	0.479
27	0.311	0.367	0.43	0.471
28	0.306	0.361	0.423	0.463
29	0.301	0.355	0.416	0.456
30	0.296	0.349	0.409	0.449
35	0.275	0.325	0.381	0.418
40	0.257	0.304	0.358	0.393
45	0.243	0.288	0.338	0.372
30	0.296	0.349	0.409	0.449
40	0.257	0.304	0.358	0.393
45	0.243	0.288	0.338	0.372
50	0.231	0.273	0.322	0.354
60	0.211	0.25	0.295	0.325
70	0.195	0.232	0.274	0.303
80	0.183	0.217	0.256	0.283
90	0.173	0.205	0.242	0.267
100	0.164	0.195	0.23	0.254

Appendix E

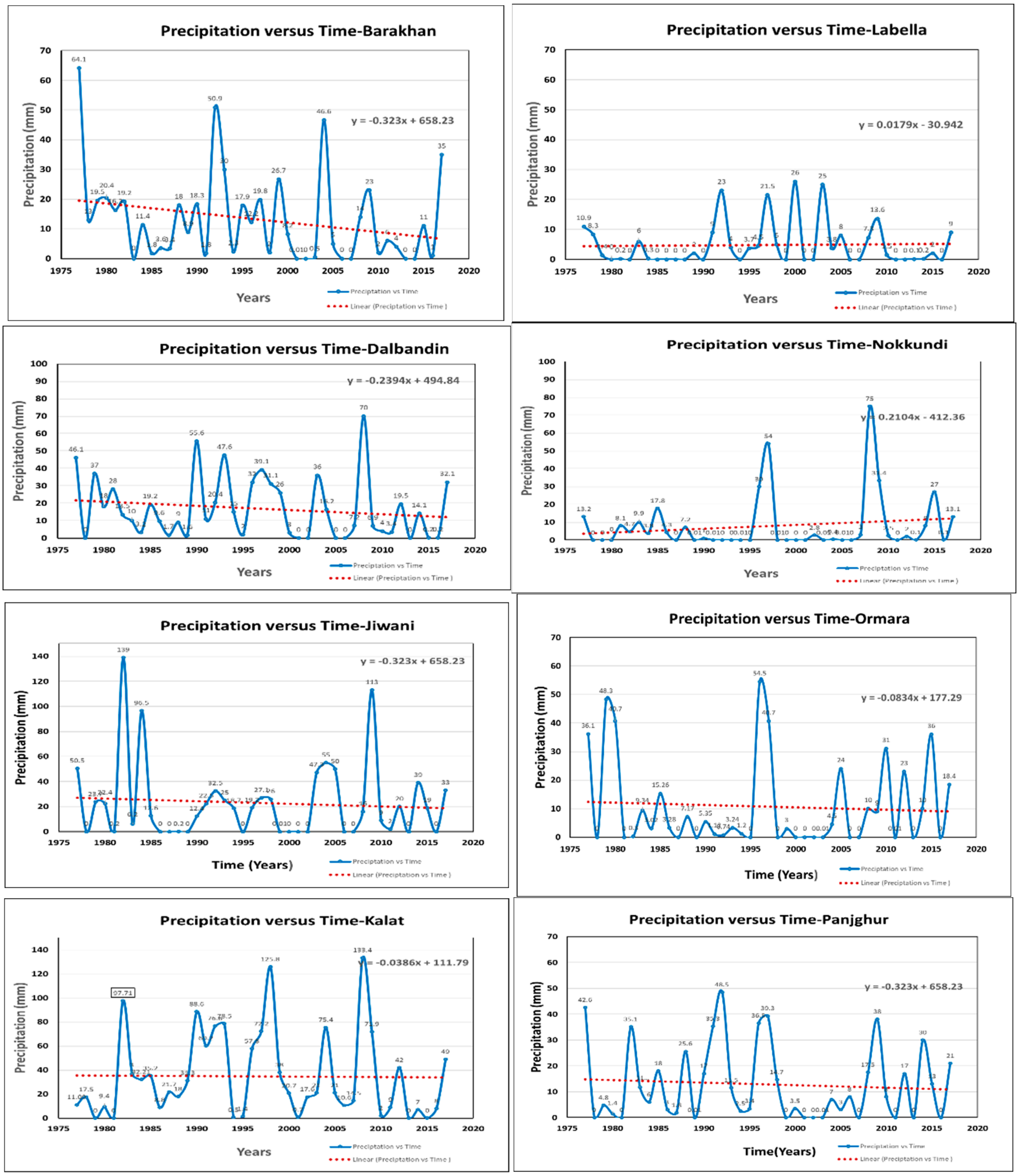

Figure A1. *Cont*.

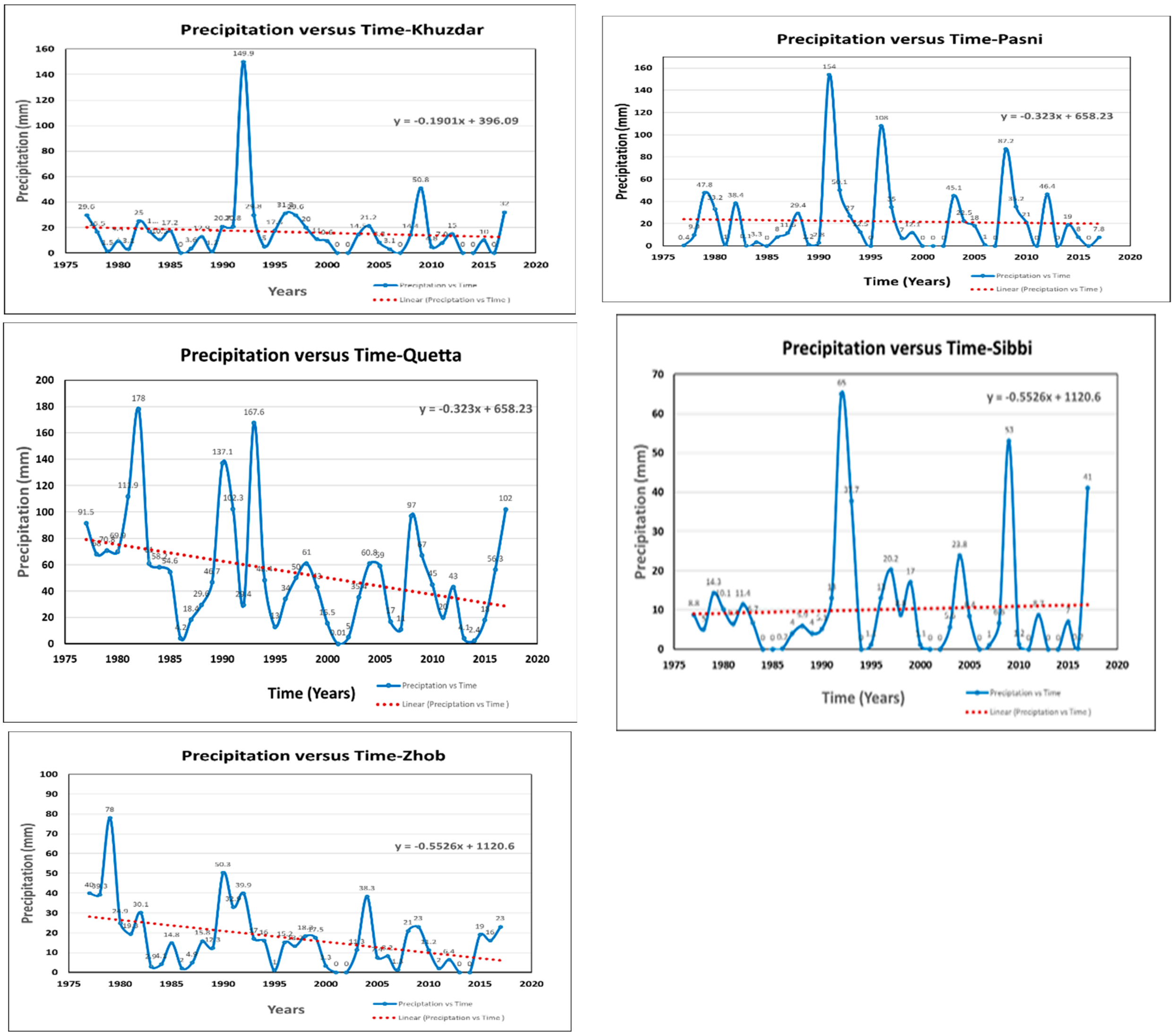

Figure A1. Graphs for January and June.

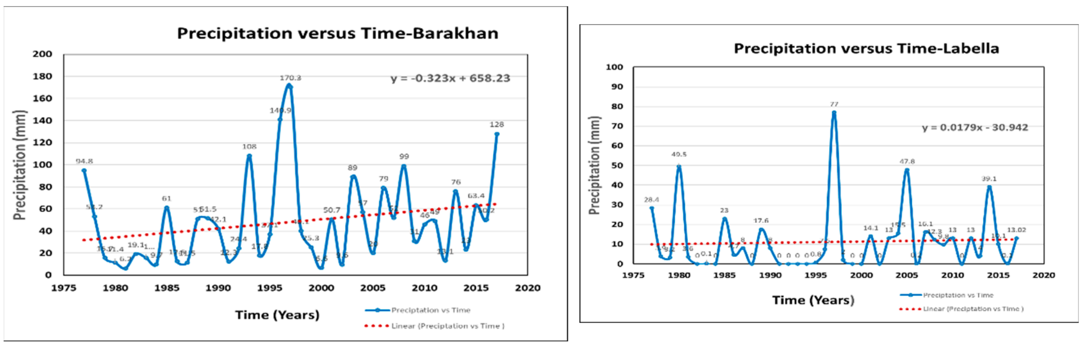

Figure A2. *Cont*.

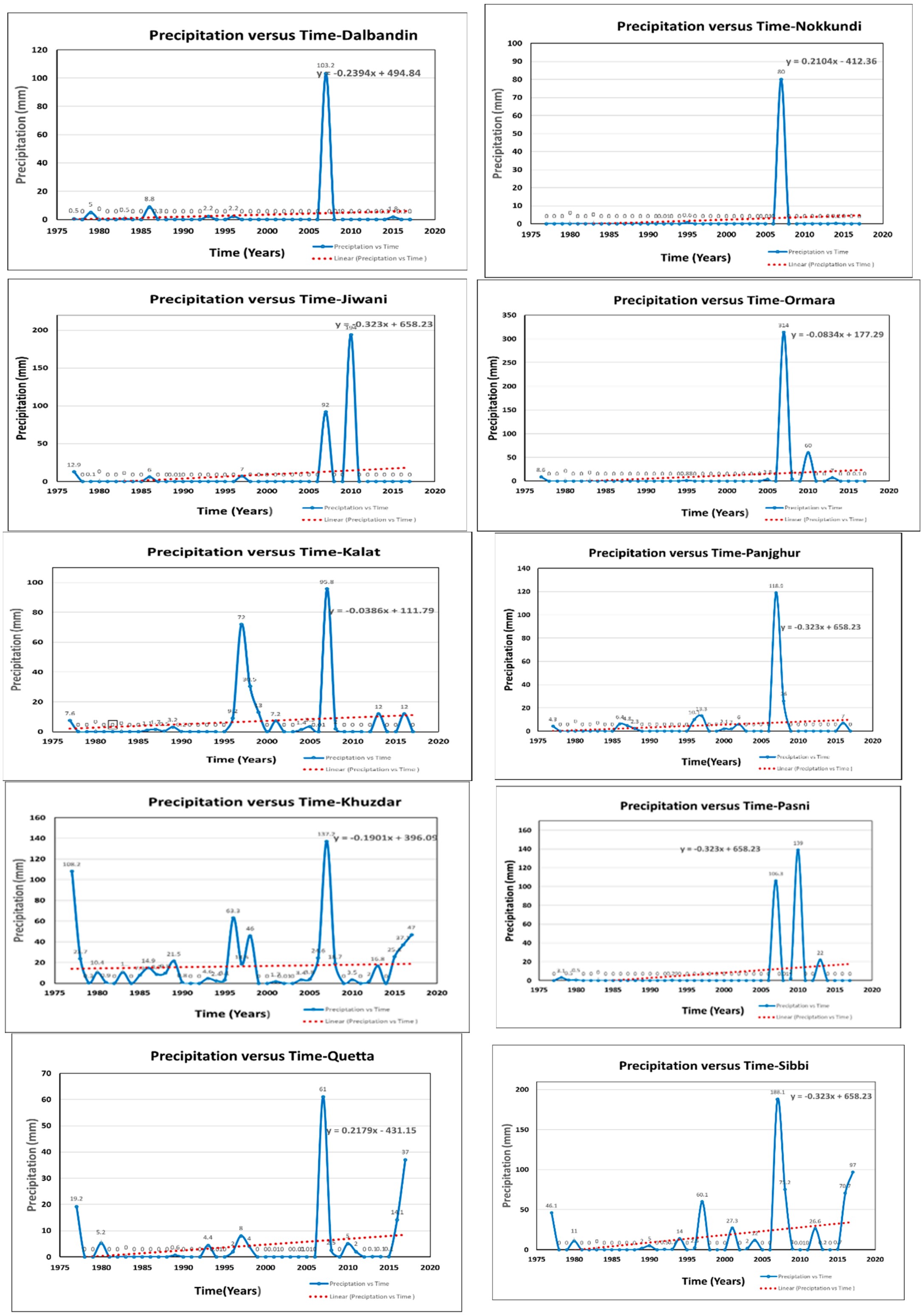

Figure A2. *Cont.*

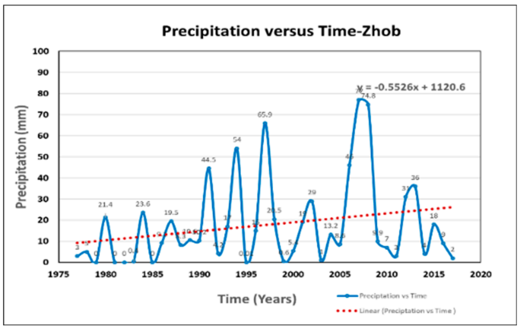

Figure A2. Graphs showing the precipitation decrements for each station as functions of time for January.

Graphs showing the precipitation decrements for each station as functions of time for June.

The precipitation graphs for each station (as functions of time) for January and June are shown in Appendix E. The trend equations are also shown on each graph. One can see that the decrement (increment) trend slopes for January and June, for which the MK and TS report significant trends (i.e., p-value < 5%), are much higher than for the other months.

References

1. Aamir, E.; Hassan, I. The impact of climate indices on precipitation variability in Baluchistan, Pakistan. *Tellus A Dyn. Meteorol. Oceanogr.* **2020**, *72*, 1–46. [CrossRef]
2. Wallace, J.M.; Gutzler, D.S. Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Weather. Rev.* **1981**, *109*, 784–812. [CrossRef]
3. Vermeer, M.; Rahmstorf, S. Global sea level linked to global temperature. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 21527–21532. [CrossRef] [PubMed]
4. Krichak, S.O.; Breitgand, J.S.; Gualdi, S.; Feldstein, S.B. Teleconnection–extreme precipitation relationships over the Mediterranean region. *Theor. Appl. Climatol.* **2014**, *117*, 679–692. [CrossRef]
5. COC. *Intergovernmental Panel on Climate Change*; World Meteorological Organization: New York, NY, USA, 2014.
6. Hussain, M.S.; Lee, S. The regional and the seasonal variability of extreme precipitation trends in Pakistan. *Asia Pac. J. Atmos. Sci.* **2013**, *49*, 421–441. [CrossRef]
7. Hussain, M.S.; Lee, S. Long-term variability and changes of the precipitation regime in Pakistan. *Asia Pac. J. Atmos. Sci.* **2014**, *50*, 271–282. [CrossRef]
8. Wang, S.Y.; Davies, R.E.; Huang, W.R.; Gillies, R.R. Pakistan's two-stage monsoon and links with the recent climate change. *J. Geophys. Res. Atmos.* **2011**, *116*, D16. [CrossRef]
9. Webster, P.J.; Toma, V.E.; Kim, H.M. Were the 2010 Pakistan floods predictable? *Geophys. Res. Lett.* **2011**, *38*, L04806. [CrossRef]
10. Bastiaanssen, W.G.; Ali, S. Ecosystems, and environment, A new crop yield forecasting model based on satellite measurements applied across the Indus Basin, Pakistan. *Agric. Ecosyst. Environ.* **2003**, *94*, 321–340. [CrossRef]
11. Eckstein, D.; Künzel, V.; Schäfer, L.; Winges, M. *Global Climate Risk Index 2020*; Germanwatch: Bonn, Germany, 2019.
12. Kreft, S.; Eckstein, D. Global Climate Risk Index 2014—Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2012 and 1993 to 2012, UK Collaborative on Development Research. 2013. Available online: https://policycommons.net/artifacts/2101506/global-climate-risk-index-2014/2856804/ (accessed on 9 June 2022).
13. Aamir, E.; Hassan, I. Trend Analysis in Precipitation at Individual and Regional Levels in Baluchistan, Pakistan. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2018; Volume 414, p. 012042.
14. Liu, D.; Guo, S.; Chen, X.; Shao, Q. Analysis of trends of annual and seasonal precipitation from 1956 to 2000 in Guangdong Province, China. *Hydrol. Sci. J.* **2012**, *57*, 358–369. [CrossRef]
15. Athar, H. Teleconnections and variability in observed rainfall over Saudi Arabia during 1978–2010. *Atmos. Sci. Lett.* **2015**, *16*, 373–379. [CrossRef]
16. Krishnamurthy, L.; Krishnamurthy, V. Indian monsoon's relation with the decadal part of PDO in observations and NCAR CCSM4. *Int. J. Climatol.* **2017**, *37*, 1824–1833. [CrossRef]
17. Liess, S.; Geller, M.A. On the relationship between QBO and distribution of tropical deep convection. *J. Geophys. Res. Atmos.* **2012**, *117*, D3. [CrossRef]
18. Afzal, M.; Haroon, M.A.; Rana, A.S.; Imran, A. Influence of North Atlantic oscillations and Southern oscillations on winter precipitation of Northern Pakistan. *Pak. J. Meteorol.* **2013**, *9*, 18.
19. Iqbal, M.F.; Athar, H. Climatology, Variability, trends, and teleconnections of observed precipitation over Pakistan. *Theor. Appl. Climatol.* **2018**, *134*, 613–632. [CrossRef]

20. Naz, F.; Dars, G.H.; Ansari, K.; Jamro, S.; Krakauer, N.Y. Drought trends in Balochistan. *Water* **2020**, *12*, 470. [CrossRef]
21. Ashraf, M.; Routray, J.K. Spatio-temporal characteristics of precipitation and drought in Balochistan Province, Pakistan. *Nat. Hazard* **2015**, *77*, 229–254. [CrossRef]
22. Ahmad, S.; Hussain, Z.; Qureshi, A.S.; Majeed, R.; Saleem, M. *Drought Mitigation in Pakistan: Current Status and Options for Future Strategies*; IWM: London, UK, 2004.
23. Ali, S.; Khalid, B.; Kiani, R.S.; Babar, R.; Nasir, S.; Rehman, N.; Adanan, M.; Goheer, M.A. Spatio-temporal variability of summer monsoon onset over Pakistan. *Asia Pac. J. Atmos. Sci.* **2020**, *56*, 147–172. [CrossRef]
24. Butt, M.J.; Iqbal, M.F. Impact of climate variability on snow cover: A case study of northern Pakistan. *Pak. J. Meteorol.* **2009**, *5*, 53–63.
25. Zahid, M.; Rasul, G.J.S.I. Frequency of extreme temperature and precipitation events in Pakistan 1965–2009. *Sci. Int.* **2011**, *23*, 313–319.
26. Hanif, M.; Khan, A.H.; Adnan, S. Latitudinal precipitation characteristics and trends in Pakistan. *J. Hydrol.* **2013**, *492*, 266–272. [CrossRef]
27. Ahmad, I.; Tang, D.; Wang, T.; Wang, M.; Wagan, B. Precipitation trends over time using Mann-Kendall and spearman's rho tests in swat river basin, Pakistan. *Adv. Meteorol.* **2015**, *2015*, 431860. [CrossRef]
28. Gadiwala, M.S.; Burke, F. Climate change and precipitation in Pakistan-a meteorological prospect. *Int. J. Econ. Environ. Geol.* **2019**, *4*, 10–15.
29. Burn, D.H.; Elnur, M.A.H. Detection of hydrologic trends and variability. *J. Hydrol.* **2002**, *255*, 107–122. [CrossRef]
30. Machiwal, D.; Jha, M.K. Time series analysis of hydrologic data for water resources planning and management: A review. *J. Hydrol. Hydromech.* **2006**, *54*, 237–257.
31. Scarpati, O.E.; Spescha, L.B.; Lay, J.A.F.; Capriolo, A.D. Soil water surplus in salado river basin and its variability during the last forty years (Buenos Aires province, Argentina). *Water* **2011**, *3*, 132–145. [CrossRef]
32. Yang, X.L.; Xu, L.R.; Liu, K.K.; Li, C.H.; Hu, J.; Xia, X.H. Trends in temperature and precipitation in the Zhangweinan River Basin during the last 53 years. *Procedia Environ. Sci.* **2012**, *13*, 1966–1974. [CrossRef]
33. Chaouche, K.; Neppel, L.; Dieulin, C.; Pujol, N.; Ladouche, B.; Martin, E.; Salas, D.; Caballero, Y. Analyses of precipitation, temperature and evapotranspiration in a French Mediterranean region in the context of climate change. *C. R. Geosci.* **2010**, *342*, 234–243. [CrossRef]
34. Verworn, H.R.; Krämer, S.; Becker, M.; Pfister, A. The Impact of Climate Change on Rainfall Runoff Statistics in the Emscher-Lippe Region. In Proceedings of the 11th International Conference on Urban Drainage, Edingburg, UK, 31 August–5 September 2008; Volume 31, pp. 1–10.
35. Towner, J.; Ficchí, A.; Cloke, H.L.; Bazo, J.; Coughlan de Perez, E.; Stephens, E.M. Influence of ENSO and tropical Atlantic climate variability on flood characteristics in the Amazon basin. *Hydrol. Earth Syst. Sci.* **2021**, *25*, 3875–3895. [CrossRef]
36. Chervenkov, H.; Slavov, K. Theil-Sen estimator vs. ordinary least squares–trend analysis for selected ETCCDI climate indices. *C. R. Acad. Bulg. Sci.* **2019**, *72*, 47–54.
37. Libiseller, C.; Grimvall, A. Performance of partial Mann–Kendall tests for trend detection in the presence of covariates. *Environ. Off. J. Int. Environ. Soc.* **2022**, *13*, 71–84. [CrossRef]
38. Van Oldenborgh, G.J.; Philip, S.Y.; Collins, M. El Niño in a changing climate: A multi-model study. *Ocean Sci.* **2005**, *1*, 81–95. [CrossRef]
39. Ashok, K.; Behera, S.K.; Rao, S.A.; Weng, H.; Yamagata, T. El Niño Modoki and its possible teleconnection. *J. Geophys. Res. Ocean.* **2007**, *112*, C11. [CrossRef]
40. Hajani, E.; Rahman, A.; Ishak, E. Trends in extreme rainfall in the state of New South Wales, Australia. *Hydrol. Sci. J.* **2017**, *62*, 2160–2174. [CrossRef]
41. Yadav, R.K.; Rupa Kumar, K.; Rajeevan, M. Increasing influence of ENSO and decreasing influence of AO/NAO in the recent decades over northwest India winter precipitation. *J. Geophys. Res. Atmos.* **2009**, *114*, D12. [CrossRef]
42. Rashid, A. Impact of El-Nino on summer monsoon rainfall of Pakistan. *Pak. J. Meteorol.* **2004**, *1*, 2.
43. Abraham, A.; Philip, N.S.; Joseph, K.B. Will We Have a Wet Summer? Soft Computing Models for Long-term Rainfall Forecasting. In Proceedings of the 15th European Simulation Conference ESM, Prague, Czech Republic, 6–9 June 2001.
44. Khan, A. The influence of La-Nina phenomena on Pakistan's precipitation. *Pak. J. Metrol.* **2004**, *1*, 23–31.
45. Adnan, M.; Rehman, N.; Sheikh, M.M.; Khan, A.A.; Mir, K.A.; Khan, M. A Influence of natural forcing phenomena on precipitation of Pakistan. *Pak. J. Meteorol.* **2016**, *12*, 24.
46. Vázquez-Patiño, A.; Campozano, L.; Ballari, D.; Córdova, M.; Samaniego, E. Virtual control volume approach to the study of climate causal flows: Identification of humidity and wind pathways of influence on rainfall in Ecuador. *Atmosphere* **2020**, *11*, 848. [CrossRef]
47. Sanabria, J.; Carrillo, C.M.; Labat, D. Unprecedented rainfall and moisture patterns during El Niño 2016 in the Eastern Pacific and Tropical Andes: Northern Peru and Ecuador. *Atmosphere* **2019**, *10*, 768. [CrossRef]
48. Chakraborty, A.; Behera, S.K.; Mujumdar, M.; Ohba, R.; Yamagata, T. Diagnosis of tropospheric moisture over Saudi Arabia and influences of IOD and ENSO. *Mon. Weather. Rev.* **2006**, *134*, 598–617. [CrossRef]