Analysis of Temperature Anomalies During the Spring Months in Jordan

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Abstract

The influence of climate change on natural resources, vegetation life cycles, precipitation, and temperature are already being noticed in Jordan and other Middle Eastern countries. This study analyzes daily, monthly, and annual temperature anomalies in Jordan. This analysis is performed based on the historical temperature dataset from eight meteorological stations during the Spring months (March, April, and May) for the period 2000 to 2018. Temperature variability was analyzed using standard deviation, variation coefficient, and trend analysis. The study also used hypotheses testing based on the Z-score test to detect temperature anomalies in daily, monthly, and annual temperature data. The results indicate that there was an increase in temperature in the last two decades. The results furthermore show that the number of temperature anomalies increased between 2016 and 2018. Temperature anomalies that exceed 1.96 occur in May whereas those that are less than -1.96 were prominent in March. Temperature anomalies occur in April more than in March and May. Also, temperature anomalies occurred after 2016 in all stations. The total anomalies days was 629. The highest percentage of the anomalies days was in March (56.60%), and May had (24.64), Whereas April had (18.76%) anomalies from the study period. These results confirm the impact of climate change on natural resources such as water, vegetation, and the biological life cycle in Jordan.

Keywords: *Climate Change, Climate of Jordan, Temperature Anomalies, Z-Score Test*

1. Introduction

Climate change particularly in the Eastern Mediterranean Basin has been intensively considered by various investigations. This is because any climate change will inevitably influence natural resources (water resources, vegetation, and animal habitats) and human activities such as agricultural and industrial activities. The effects of climate change are already being noticed in increasing temperature, heat waves, meteorological instability cases, frequency and severity of the flood, and rainfall reduction in Jordan and other Middle Eastern countries. The climate of Jordan is influenced by the Mediterranean climate, which is characterized by dry summers and mild wet winters. Jordan is also affected more than ever by the Red Sea low, particularly in the spring and autumn seasons. In recent years, the climate in Jordan has been affected due to global warming. One of the prominent changes that have been noticed is an increase in the spring season temperature.

Climate change during the current century is expected to affect most of the climate elements in Jordan [1]. The average maximum temperature increased between (0.3 - 1.8 °C) in the last five decades (UNFCCC, 2009). Climate models also expected an increase in the annual average temperature in the Middle East to (4.5) °C. In Jordan, it is expected that the temperature rise will reach 2 °C, [2]. The expected increase in global temperature by 2100 is expected to reach 4 °C [3]. It is the expected increase in temperature in the Mediterranean basin. Most of the increase in temperature in the Mediterranean basin will especially affect summer temperature and will be higher than any increase in summer temperature anywhere in the world [4]. The models of the general cycle of the atmosphere expect that in most areas of the Mediterranean basin, drought will increase in severity and frequency south of latitude (40-45) [3]. Extremes are expected to increase floods, drought, and heat waves [1]. Warming has resulted in an increased frequency, intensity, and duration of heat-related events. Temperature anomalies have been studied on the country, content, and global scales.

On a global scale, [5] analyzed monthly temperatures over land and oceans between 1881 and 2020 and found that temperature anomalies have significantly increased during the previous five decades due to anthropogenic activities [6] investigated the trend analysis of the minimum and maximum temperature in Addis Ababa, Ethiopia, and found that there is a significant increase in temperature. Similarly, [7] investigated the trend analysis of temperature in Gombe State using the Mann-Kendall trend test. The study found an increasing trend of the maximum and average temperatures. Over the Mediterranean region, [8] found A statistically significant negative trend during 1960–1976 and a positive one during 1977–2004 were revealed in Greece.

The east Mediterranean, including Jordan, becomes part of the tropical jet stream in summer and part of the Siberian Jet Stream in winter. There are many studies conducted and publications made to examine the different features of the region. But there is a lack to be seen particularly of the studies regarding the examination of anomalies in spring temperature covering the selected stations or using daily mean temperature. The study is therefore deemed to be important in terms of revealing the changes in Jordan's climate during the period between the years 2000 and 2018. This study comes to addresses temperature anomalies during the spring months (March, April, and May) in Jordan. The daily temperature of the abovementioned months for the period 2000 to 2018 is analyzed using statistical approaches such as linear regression, *Z-score* test, and hypotheses testing to detect the anomalies in the daily temperature. Also, the temperature changes are mapped using interpolation techniques (IDW). This is to show how the temperature during the spring months is changed spatially and temporarily in Jordan.

2. Study Area, Materials and Methods

2.1 Study Area

Jordan is located in northwestern Asia (34° 52´ to 39° 15´ N and 31° to 59° E), with an approximate area of 89,300 km² (Figure 1). Jordan lies to the east of the Mediterranean Sea, and its climate is characterized by diversity among the seasons of the year where the summer and winter seasons are the longest seasons. In general, the climate of Jordan is dry in summer and modestly wet in winter [9] where the annual average temperature and precipitation are around 19 °C and 90mm respectively. A huge part of Jordan, particularly the central and northern regions, has a Mediterranean climate, whereas, the desert and semi-desert climate prevail in the southern and eastern areas. The semi-tropical climate prevails in the Jordan Valley. The spring months which extend from 23rd March to 20th June are a transitional period between the winter and summer. These months witness some climate instability cases and thunderstorms as a result of the impact of the Red Sea Trough (RST), dust storms, and the Khamsin Trough.

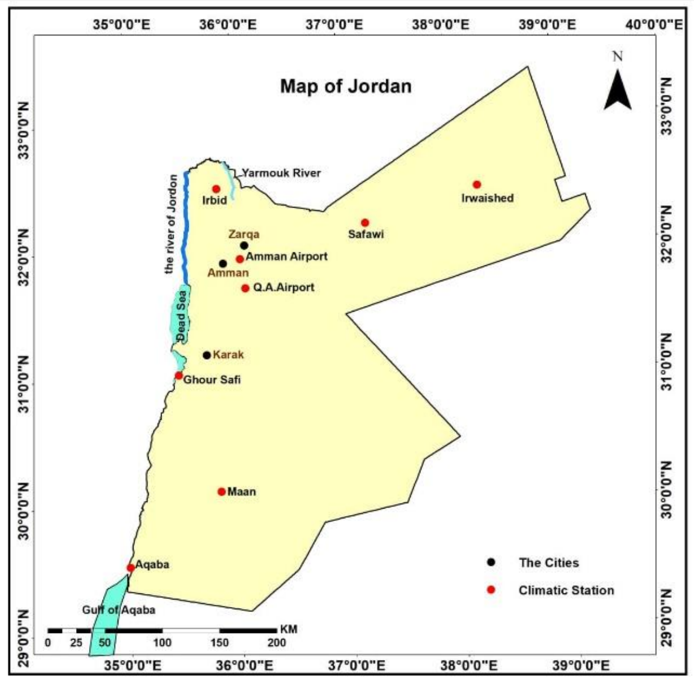

Figure 1: The geographical location of Jordan and the distribution of meteorological stations

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Table 1: Characteristics of the meteorological stations used in this research

Station	ID.No.	Longitude	Latitude	Altitude [m]
Irbid	402550	35° 85´	32° 54´	618
Aqaba Airport	403400	35° 01´	29° 55´	53
Irwaished	402500	38° 02´	32° 50´	686
Q.Alia Airport	402720	35° 96´	31° 71´	721
Maan	403100	35° 78´	30° 16´	1069
Ghour Safi	402960	35° 46´	31° 03´	-350
Safawi	402600	37° 13´	32° 02´	668
Amman Airport	402700	35° 98´	31° 98´	767

2.2 Dataset

Daily temperature records during the spring months (March, April, and May) for the period 2000-2018 were obtained from eight meteorological stations spread over the study area (Figure 1). The characteristics of these stations are shown in Table 1. The maximum, minimum, and average daily temperatures were calculated to achieve the goal of this research. In this research, temperature anomalies are calculated on an annual, monthly, and daily basis. Thus, several mathematical notations are used to clarify the concepts. The annual mean temperature represents the total temperature of the spring months (March, April, and May) divided by three. The total temperature from 2000 to 2018 during March, April, and May divided by the number of years (here 19 years) represents the general monthly mean temperature whereas the monthly mean is the total daily temperature divided by the number of days in the month. The daily temperature is the average hourly temperature divided by the number of temperature records during a day. Note that the number of records during the day varies from one station to another.

3. Methods

A statistical approach was used to analyze temperature data including moving average, standard deviation, and variation coefficients. For anomaly detection in the daily temperature, hypotheses testing based on a z-score test was employed.

3.1 Variation in Daily and Monthly Temperature

To illustrate short-term fluctuations in a time series with the base period 2000–2019, The 3-year moving average (*MA*) were used. The *MA* can be computed from Equation 1 [10] and [11]:

$$MA = \frac{\sum_{i=1}^{n} M(d-i)+1}{n}$$

Equation 1

Where n is the number of data, d is the moving average, and M is the Data calculated as the simple moving average when the period is 3. The mean temperature $\bar{T}_i$ can be calculated from the daily (T_d) and monthly (T_m) temperature data from Equation 2 [12]:

$$\bar{T}_i = \frac{1}{n}\sum_{i=1}^{n} T_i$$

Equation 2

Where T denotes monthly or daily temperature data. In addition, the variance and standard deviation of daily, monthly, or annual temperature are calculated to demonstrate the variation of temperature as a function of time from Equation 3 [9]:

$$TM_{\text{var}\,ience} = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{m}\left(T_i - \bar{T}_i\right)^2}}{\bar{T}_i}$$

Equation 3

3.2 Anomalies Detection

Hypotheses testing was used to test whether the temperature data include anomalies or not. This can be performed based on a *Z-score* test. The *Z-score* (φ_{ij}) test can be written in Equation 4 [13]:

$$\varphi_i = \frac{T_i - \bar{T}_i}{\sigma_i}$$

Equation 4

In this research, the significant level is 0.95 with alpha (α) equal to 0.05. Thus, the critical value of the *Z-score* is +1.96 and -1.96 for two tails test [13]. The null and alternative hypotheses can thus be written in Equation 5:

$$H_0: -1.96 \le \varphi_i \le 1.96$$
$$H_1: \varphi_i < -1.96, \text{ and } \varphi_i > 1.96$$

Equation 5

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The *Z-Score* was calculated for all meteorological stations to detect anomalies daily during the spring months.

3.3 Trend Analysis

To show the variability of temperature as a function of time, trend analysis is employed in Equation 6 [14] and [15]:

$$X_i = X_{trend(i)} + S_i X_{Noise(i)}$$

Equation 6

Where:

X_i is the variability of temperature over time (i) (daily, monthly, annually) in degrees Celsius.

$X_{trend(i)}$ is the variability of temperature over time (i) (daily, monthly, annually) without noise in degrees Celsius.

$X_{Noise(i)}$ is the zero-mean noise over time

S_i is the time-dependent scaling function

The statistical regression of the trend can be performed by the time series of the temperature $\{t_i, x_i\}$where t_i is the time and x_i is the temperature, $i=1,2,3\ldots, n$. From the time series of the temperature, the simple linear regression of the trend can be written in Equation 7:

$$X_i = \alpha + \beta t_i + S_i X_{Noise(i)}$$

Equation 7

where α and β are parameters namely the intercept and slope respectively.

4. Results and Discussion

4.1 Aannual Mean Temperature Trend

Figure 2 shows the annual mean temperature trend and moving average in Jordan after smoothing out short-term fluctuations in a time series. As can be seen, there is an increasing trend between 2000 and 2018 in the 3-year moving average as well as in the mean annual. One can notice that there is a prominent increase after 2011 in both the annual average and the 3-year moving average. This confirms that the annual temperature in Jordan in the last decade has considerably increased due to global warming. Figure 3 demonstrates the annual and 3-year moving average during the spring months between 2000 and 2018. Generally speaking, the temperature during the spring months in almost all stations began to increase in the last two decades. Additionally, stations which are located in the south and southeastern part of the study such as Aqaba Airport, Al-Ruwaished, Maan, Safawi, and Queen Alia Airport exhibit a steady increase in annual temperature during the spring months. The location of these stations is within the desert climate zone. Thus, they are far away from the influences of the Mediterranean humid wind. The annual temperature in other stations (Irbid and Amman Civil Airport) has also increased but with fluctuations. This is because these stations are located in the western and northwestern part of the study area where the influence of the western humid winds is prominent in this climate zone, (the Mediterranean climate zone) [16] and [17]. The location of Ghour Al-Safi in Jordan Valley (350m below sea level) leads to an increase in the temperature with less fluctuation than the other two stations.

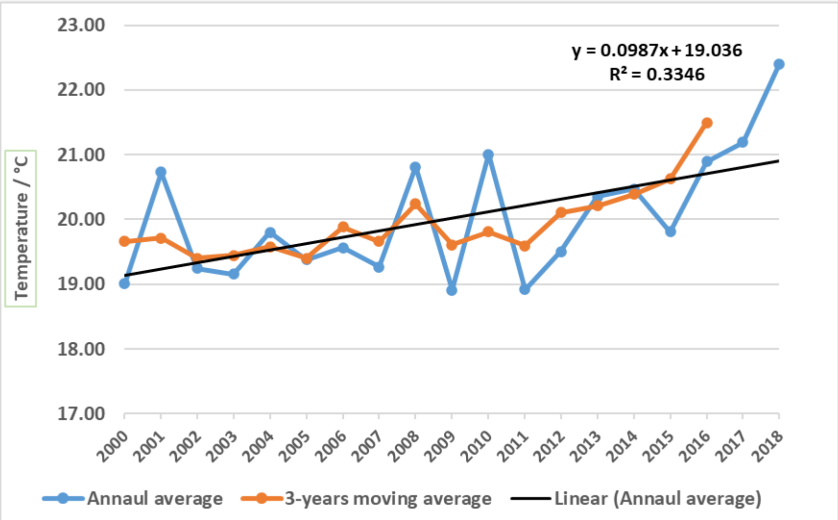

Figure 2: Annual mean temperature and the 3-year moving average temperature in Jordan between 2000 and 2018

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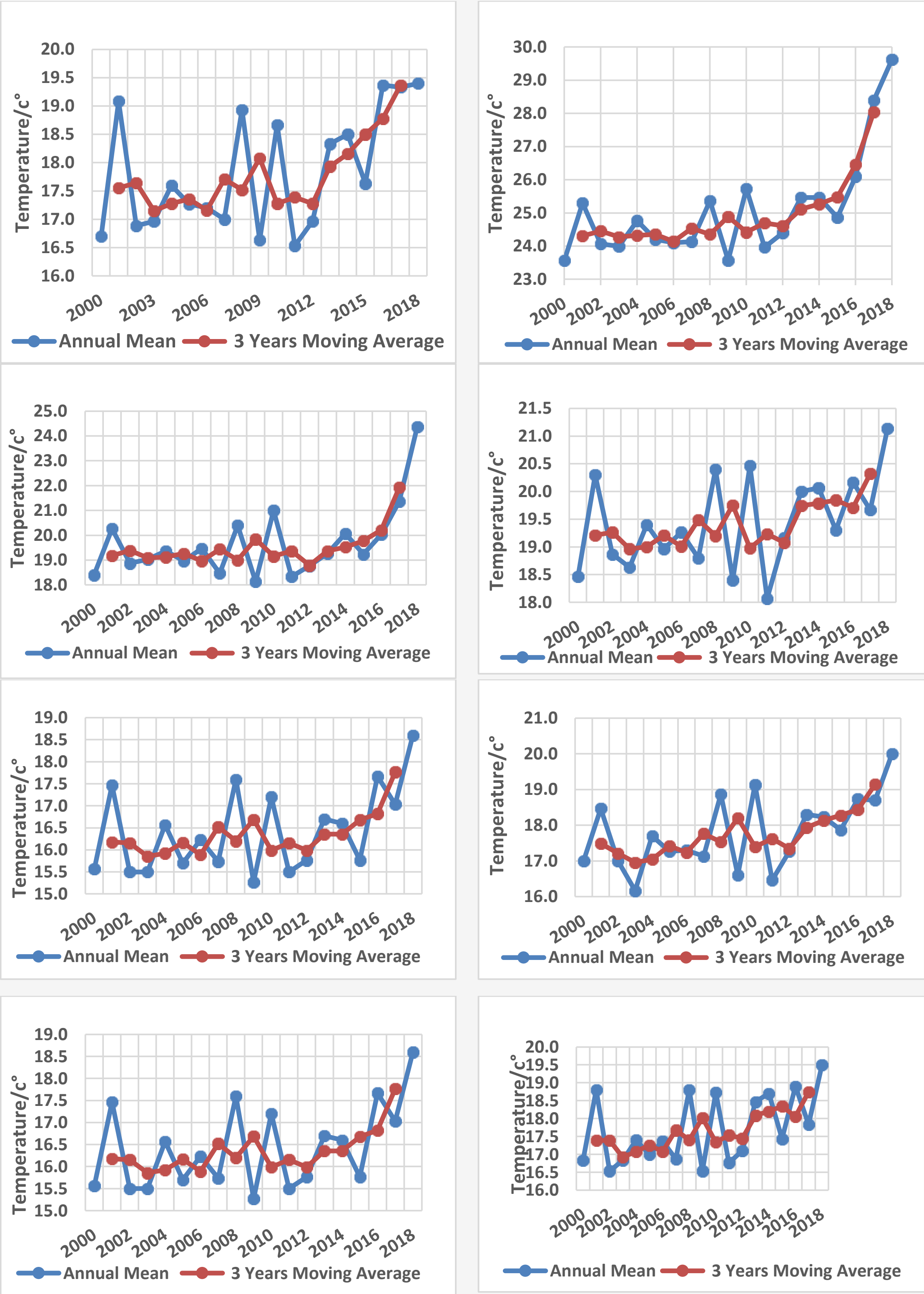

Figure 3: The annual and the 3-year moving average of temperature in meteorological stations during the spring months between 2000 and 2018 (a) Irbid, (b) Aqaaba airport,(c) Irwaished, (d) Safawi, (e) Q. A. Airport, (f) Maan, (G) Ghour Safi, (h) Amman airport

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4.2 Anomalies Detection

Figure 4 shows the *Z-score* values of the spring months (March, April, and May) for the period 2000-2018 in all meteorological stations. As can be seen, the highest Z-score values of approximately 1.5 and 1.6 are in the Aqaba airport and Ghour Al-Safi stations respectively. The lowest values on the other hand are in Irwaished and Safawi with values ranging between -20 and 4. The rest of the stations have *Z-score* values ranging between 0 to -1. This means that no anomalies are detected because the *Z-score* values in all months and stations do not exceed the critical value of 1.96 or -1.96.

Figure 5 illustrates the annual variation in *Z-score* values in March, April, and May. As normal, the *Z-score* values fluctuate between positive and negative values in all stations. Additionally, one can notice that most of the stations recorded high *Z-score* values that exceed 1.96 in April and May in 2017 and 2018. This means that these two years have temperature anomalies during April and May. Notably, the temperature during May 2004 exceeds 1.96 in Irbid, Goour Safi, Queen Alia Airport, and Amman Airport stations. Also, it can be noticed that the temperature was the lowest during March 2004 in all stations where some stations (Irbid, Safawi, Maan, Queen Alia Airport, and Amman Airport) have a value of the *Z-score* less than -1.96. Table 2 summarizes the *Z-score* values in the period 2000-2018 during March, April, and May in all meteorological stations. Temperature anomalies occur in April more than in March and May. Also, one can notice that temperature anomalies occurred after 2016 in all stations. This confirms a pronounced increase in temperature in the last decade due to global warming.

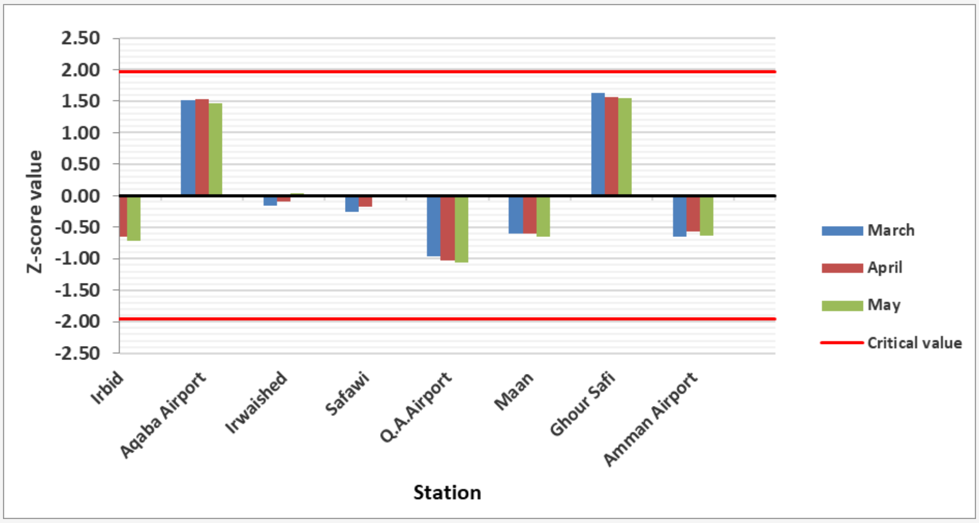

Figure 4: *Z-score* values of the mean annual temperature during the spring months in all stations

Table 2: *Z-score* values in the period 2000-2018 during March, April, and May in all meteoroidal stations

Station	Year	March	April	May
Irbid	2016	-	2.24	-
Aqaba airport	2017	-	2.27	2.08
	2018	-	2.21	2.64
Irwaished	2018	2.61	2.48	2.70
Safawi	2016	-	1.97	-
	2018	-	-	1.10
Q.A. airport	2016	-	2.03	-
	2018	-	-	2.09
Maan	2018	2.05	-	-
	2018	-	-	2.35
Ghor Safi	2003	-	2.01	-
	2016	-	-	2.55
Amman airport	2018	-	2.58	2.09

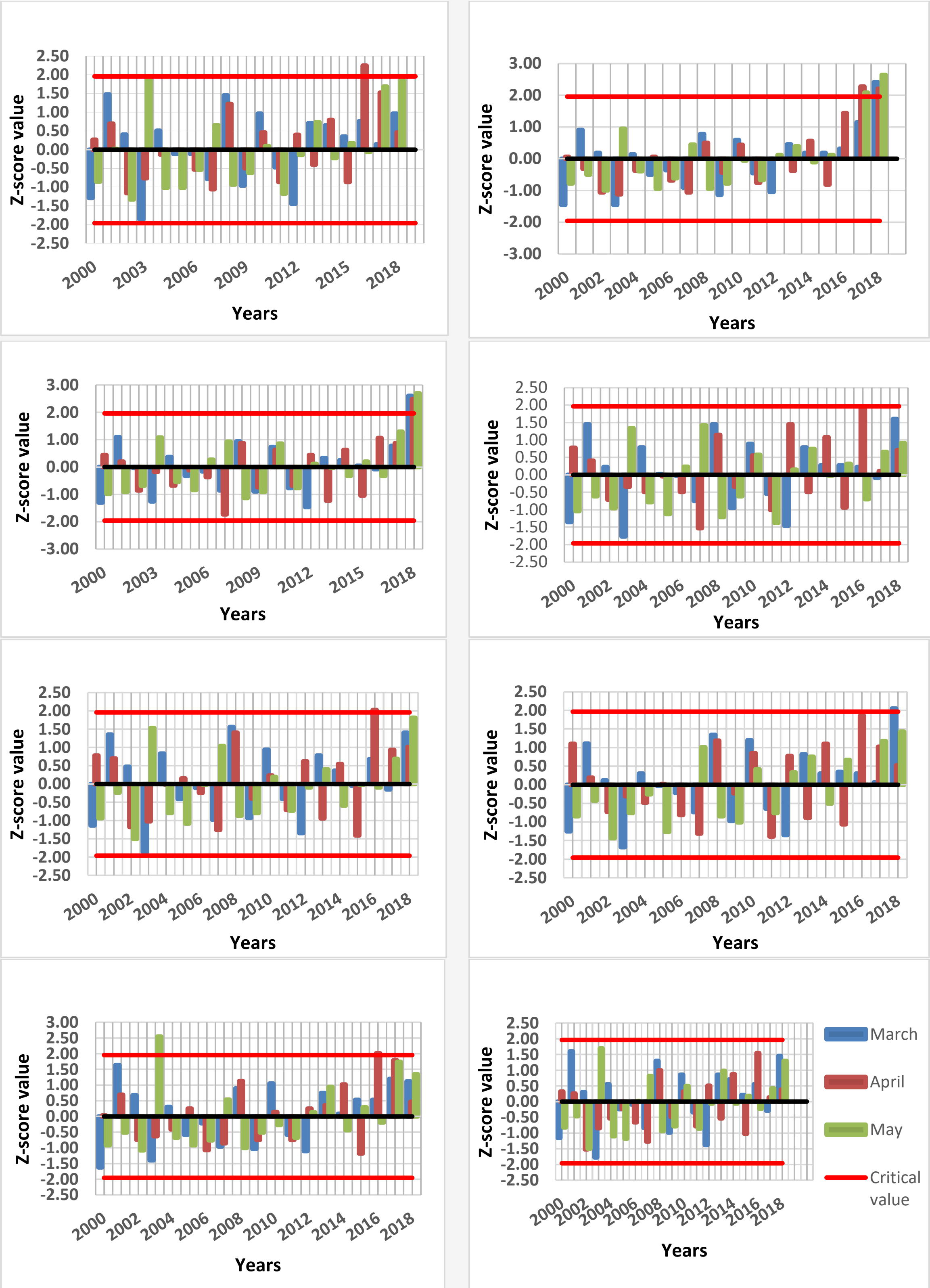

Figure 5: Annual variation in *Z-score* values for March, April, and May (a) Irbid, (b) Aqaaba airport, (c) Irwaished, (d) Safawi, (e) Q.A.Airport, (f) Maan, (G) Ghour Safi, (h) Amman airport

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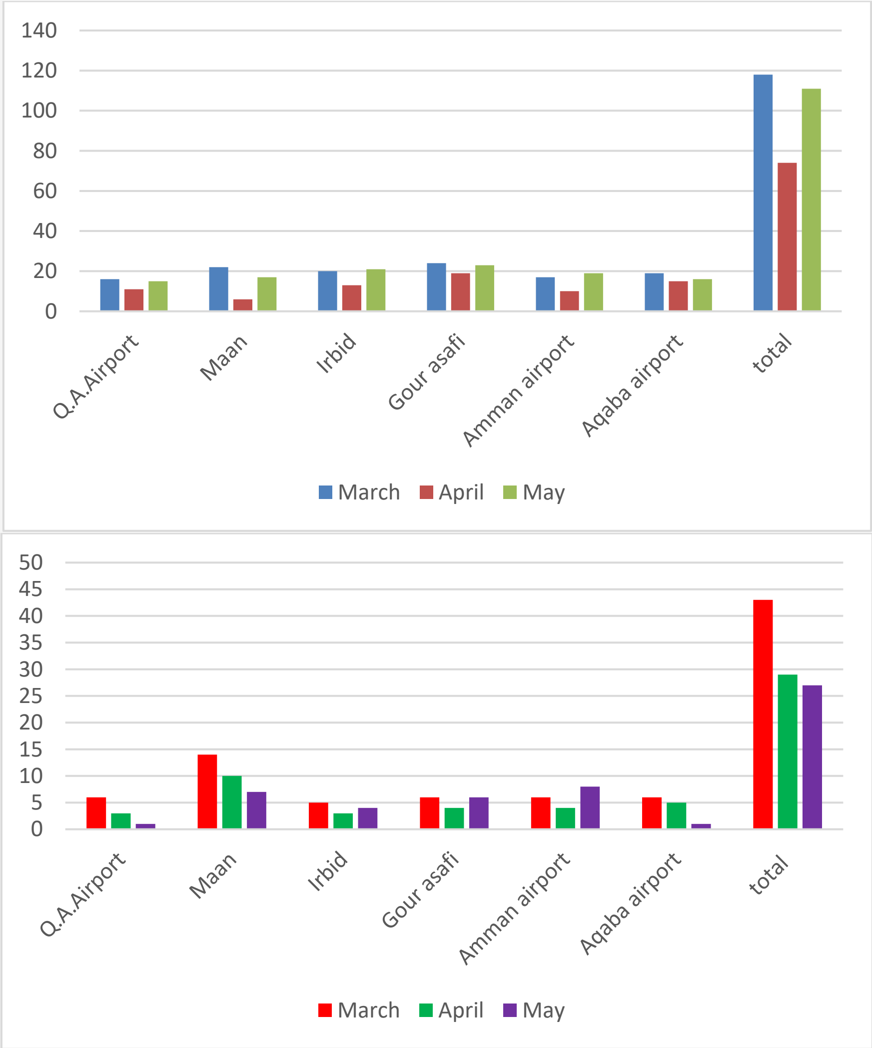

Figure 6: Number of the daily positive (up) and negative (bottom) temperature anomalies in March, April, and May

To show daily temperature anomalies during March, April, and May for the period 2000-2018, Figure 6 shows the number of days in each meteorological station when the *Z-score* values are greater or less than 1.96 and -1.96 respectively. note that due to the missing daily temperature data in two meteorological stations namely Irwaished and Safawi, they were omitted from the analysis. Generally speaking, the number of days with positive temperature anomalies in March is higher than that in April and May in almost all stations (except Amman Airport station). As can be seen, the highest number of anomalies in March is in Gour Asafi Station (24 days), followed by Maan and Irbid (20 days. Also, the total number of anomalies in May is higher than those in April in almost all stations. This means that March and May exhibit a high number of daily temperature anomalies because they are in a transition period between Winter/Spring and Spring/summer respectively.

For the negative temperature anomalies, it can be seen that March exhibits the highest number of temperature anomalies among the other two months in almost all stations (except Amman airport station). However, the number of days with negative anomalies is the lowest in May. This is because the Z-score values in March are prone to negative more than positive because this month is considered a transition between Winter and Spring, thus most of the anomalies are negative (less than -1.96) and very few days exceed 1.96. In May however, most of the daily temperature anomalies are positive because this is the last month in the Spring where the study area is influenced by the dry Khamasin and Red Sea Trough (RST). Therefore, most of the daily temperature anomalies are above 1.96.

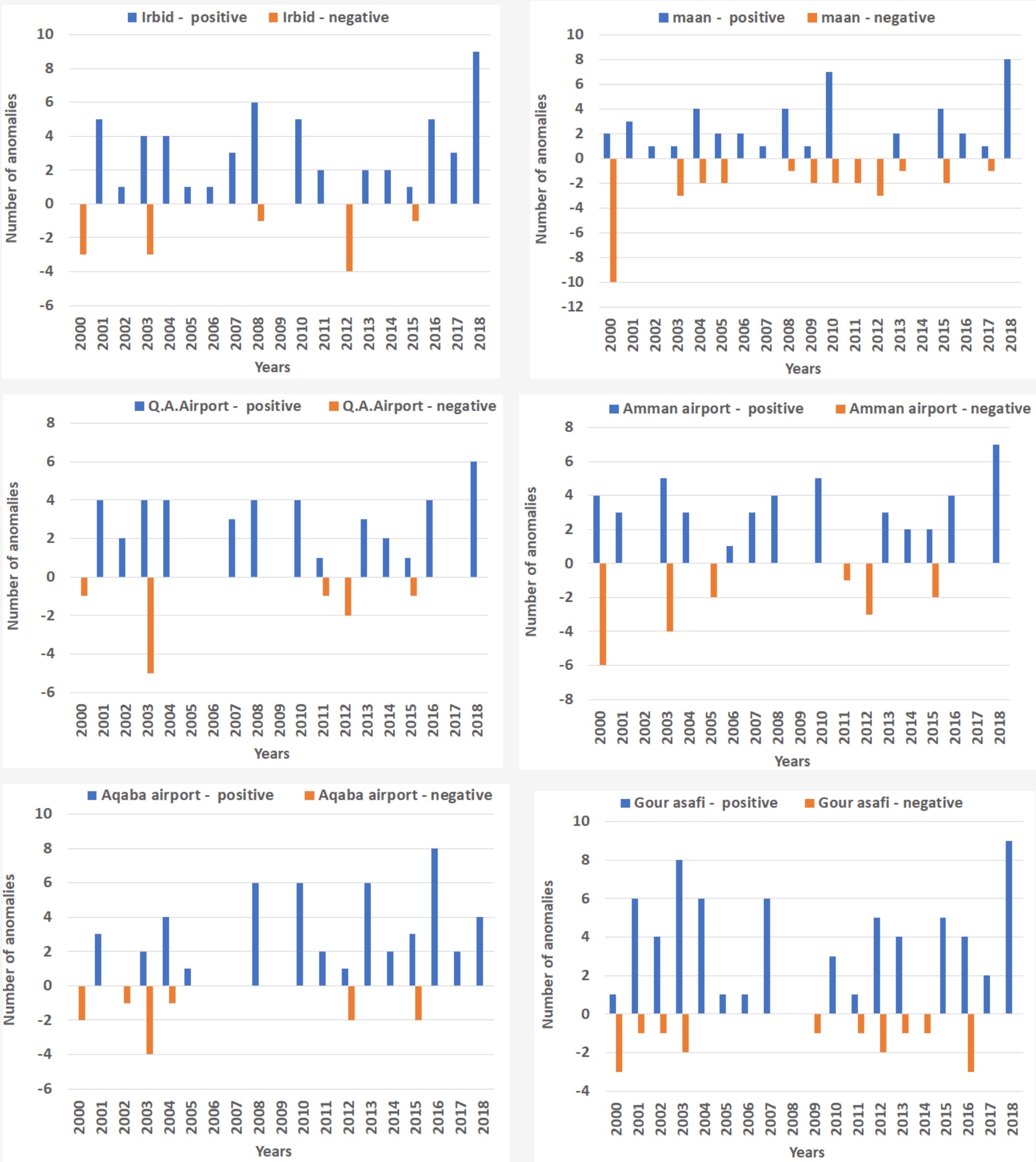

Figure 7: Number of daily temperature anomalies in meteorological stations in the period (2000-2018)

Figure 7 demonstrates the number of daily positive and negative temperature anomalies over the period 2000-2018 during the spring months. It is clear that the highest number of daily positive anomalies is in 2018 in almost all the stations except Aqaba Airport station. Additionally, the number of daily positive anomalies is more than that of daily negative anomalies in all stations. It can also be noticed that the total number of daily negative anomalies occurred between 2000 and 2010 whereas the positive anomalies occurred between 2010 and 2018. This means that the temperature prone to increase in the last decade.

5. Conclusions

The temperature during the spring months in almost all stations began to increase in the last two decades. Temperature anomalies are clear evidence of the impact of climate change on natural resources and the biological life cycle. This study analyzes daily, monthly, and annual temperature anomalies in Jordan. The analysis was performed over the Spring months (March, April, and May) for the period 2000 to 2018. The analysis was based on the historical records of temperature from 8 meteorological stations spread over the study area. Results showed a significant increase in daily, monthly, and annual temperature anomalies in the period 2016-2018 compared with the previous periods. Most of the stations recorded high *Z-score* values that exceed 1.96 in April and May in 2017 and 2018. This means that these two years have temperature anomalies during April and May. Temperature anomalies occur in April more than in March and May. Also, temperature anomalies occurred after 2016 in all stations. The total anomalies days was 629, distributed as: March 356 days, May 155 days and April 118 days. The highest percentage of the anomalies days was in March (56.60%), and May had (24.64), Whereas April had (18.76%) anomalies from the study period. The results also revealed that most of the temperature anomalies in terms of severity and frequency occur during May and March. This is because these two months transit between the Spring/Summer and Winter/Spring respectively. this confirms that the impact of climate change on increasing temperatures is clear in the last decade. The study recommends a more thorough investigation of the impact of climate change on other climate elements such as precipitation, humidity, and land surface temperature in the future.

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References

[1] Shehadeh, N., (2013). Climatology, Amman, Jordan. Dar Safa for Publishing and Distribution.

[2] Oroud, I. M., (2008). The Impacts of Climate Change on Water Resources in Jordan. *Climatic changes and Water Resources in the Middle East and North Africa*. Springer, Berlin, Heidelberg. 109-123.

[3] Karas, J., (2007). *Climatic Change and the Mediterranean*,1- 29.

[4] Solomon, S.D., Qin, D., Manning, M., Chen, Z., Marquis, M., Avery, K.B., Tignor, M., and Miller, H.L., (2007). *Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the IPCC.*

[5] Sadhukhan, B., Mukherjee, S. and Samanta, R. K., (2022). A Study of Global Temperature Anomalies and their Changing Trends due to Global Warming. *2022 14th International Conference on Computational Intelligence and Communication Networks (CICN), Dec. 2022*, 660–666. http://dx.doi.org/10.1109/cicn56167.2022.10008329.

[6] Alemu, Z. A. and Dioha, M. O., (2020). Climate change and trend Analysis of Temperature: The Case of Addis Ababa, Ethiopia. *Environ Syst Res*, Vol. 9(10). https://doi.org/10.1186/s40068-020-00190-5.

[7] Alhaji, U. U., Yusuf, A. S., Edet, C. O., Oche, C. and Agbo, E. P., (2018). Trend Analysis of Temperature in Gombe State Using Mann Kendall Trend Test. *Journal of Scientific Research & Reports*, Vol. 20(3), 1-9. https://doi.org/10.9734/JSRR/2018/42029.

[8] Mamara, A., Argiriou, A. A. and Anadranistakis, M., (2016). Recent Trend Analysis of Mean Air Temperature in Greece Based on Homogenized Data. *Theor. Appl. Climatol.* Vol. 126, 543–573. https://doi.org/10.1007/s00704-015-1592-x.

[9] Almagbile, A., Zeitoun, M., Hazaymeh, K., Sammour, H. and Sababha, N., (2019). Statistical Analysis of Estimated and Observed Soil Moisture in Sub-humid Climate in North-western Jordan. *Environmental Monitoring and Assessment*, Vol. 191. 543–573. https://doi.org/10.1007/s10661-019-7230-9.

[10] Carpenter, T., Kettenring, J. and Vanderbei, R., (2013). Statistical Exploration of Climate Data, Instructor Module. *DIMACS/Mathematics of Planet Earth*, 1-22. http://archive.dimacs.rutgers.edu/MPE/Climate/weather-module-instructor-V1.pdf.

[11] Hansen, J. W., Mason, S. J., Sun, L. and Tall, A., (2011). Review of Seasonal Climate Forecasting for Agriculture in Sub-Saharan Africa. *Experimental Agriculture*, Vol. 47(2), 205-240. https://doi.org/10.1017/S0014479710000876.

[12] Kawale, J., Chatterjee, S., Kumar, A., Liess, S., Steinbach, M. S. and Kumar, V., (2011). Anomaly Construction in Climate Data: Issues and Challenges. *Proceedings of the 2011 Conference on Intelligent Data Understanding, CIDU 2011, October 19-21, 2011, Mountain View, California, USA*, 189-203.

[13] Adams, K. A. and Lawrence, E. K., (2018). *Research Methods, Statistics, and Applications*. Sage Publications.

[14] Mudelsee, M., (2019). Trend Analysis of Climate Time Series: A Review of Methods. *Earth-Science Reviews*, Vol. 190, 310-322. https://doi.org/10.1016/j.earscirev.2018.12.005.

[15] Kafle, H. K. and Bruins, H. J., (2009). Climatic Trends in Israel 1970–2002: Warmer and Increasing Aridity Inland. *Climatic Change*, Vol. 96(1), 63-77. https://doi.org/10.1007/s10584-009-9578-2.

[16] Zeitoun, M., Al-Maqbel, A. and Al-Shayab, S., (2022). Analysing the Weather Conditions Accompanying the Rainy Days in the Dry Year 2007/2008 and the Wet Year 2002/2003. *Dirasat: Human and Social Sciences*, Vol. 49(2), 147–165. https://doi.org/10.35516/hum.v49i2.1782.

[17] Zytoon, M. and Shehadeh, N., (2016). Climate Change Indicators in the North of Jordan. *Dirasat: Human and Social Sciences*, Vol. 42(2). https://archives.ju.edu.jo/index.php/hum/article/view/11539.