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Monthly and Seasonal Trend Analysis of Maximum Temperatures over Turkey

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Abstract:
Global warming and climate change are important environmental, economic and social issue all over the world. In this paper, maximum temperature records were analyzed monthly and seasonally. In the study, trend calculation was applied over Turkey by using homogenized daily maximum temperature data of 165 climatological stations in the period 1961-2008. Temperature records were divided into two equal periods. Calculations were applied to all stations by using differences between the last half period and the whole period. The aim of the study was to better understand the reasons of monthly and seasonal trends in maximum temperatures. The Swed-Eisenhart Run test was applied to all stations in order to homogenize the data. It can be clearly seen that there was a considerable increase in maximum temperatures. Increasing trends were comparatively stronger than decreasing trends for all seasons. Especially in summer season, the percentage of increasing trends was above 90% which was the highest of all seasons.

Keywords: Global warming, Homogeneity, Trend analysis, Temperature, Turkey

1. INTRODUCTION:

Global warming is one of the greatest environmental, economic and social threats the Earth is facing. There are many assessments to estimate climate variability over many regions of the world. It is confirmed that the Earth's average temperature increased within the last century. This change leads to increase in extreme temperature events.

The IPCC (2001) defines an extreme event as follows: '*An extreme weather event is an event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile*' [1].

Long lasting extreme events such as heat waves, dry spells are harmful to the ecosystem. Besides, they create danger on human health. As a result of global climate change effects on Earth, an increasing tendency in temperature was observed in a global scale.

Temperature of the earth increased in the last 150 years based on global measurements. If the increases were expressed in the two periods, one was from earlier of 1900s to 1940s (0.35°C) and other was from 1970s to present that was exacerbated by 0.55°C and the highest temperature measurement was observed in the last 12 years.

IPCC 4th Assessment Report revealed that global average temperature increased about 0.74°C within last century and it is expected to rise even faster in the 21th century. This increasing temperature trend over the years caused to an increment of the high land temperatures, increase in winter temperatures and decline in the observed extreme cold days and nights according to the increasing incidence of extreme hot days and nights [2]. It means that in a future warmer climate with increased mean temperatures, so extreme events would become more intense, longer lasting, and more frequent [3]. Tonkaz and Çetin (2007) calculated the monthly temperature trends using nonparametric Mann-Kendall test procedure for 16 observation stations in GAP area (Southeast of Turkey). Data records between 1932 and 2002 were used for trend analysis. The results showed that the monthly maximum and minimum temperature trends moved considerably upward [4].

Founda et al. utilized the 105-year (1897-2001) surface air temperature data of the National Observatory of Athens (NOA) to calculate the mean, maximum and minimum temperature trends in Athens. Considerably warmer spring and summer seasons and mildly warmer winters were realized. Additionally, while warm events had an increasing tendency, the number of days with cold events decreased significantly [5]. In previous studies was expressed that especially, the year in spring and winter average temperatures increased in southern parts of Turkey and corresponding average autumn and summer temperatures decrease in north and inland continental areas [6].

Determining the tendency of updated regional mean temperature increased or decreased in the trend analysis studies constitute an important resource for future climatological researches. In this study, a trend analysis was applied to Turkey which has the different regional climate characteristics. Homogenized maximum temperature data for 165 climatological stations were used in the study between 1961 and 2008 years.

2. STUDY AREA, DATA AND METHODOLOGY:

Figure 1 shows the locations of the stations used in this study. The data used in this research were provided by Turkish State Meteorological Service (MGM). A total of 165 stations across the country were used to determine and examine trend during the period 1961-2008.

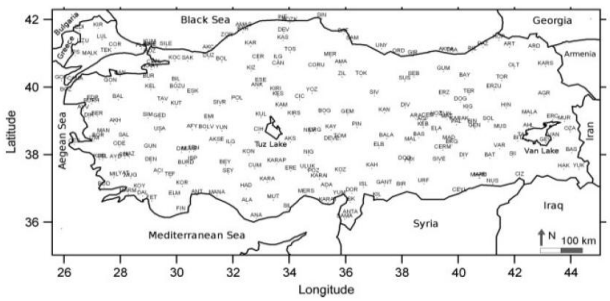


Figure.1. Locations of climatological stations used in study. [7]

In this paper, temperature records were divided into two equal periods. The first period represented an early part from 1961 to 1984, and the following part was between the years of 1985 and 2008. The aim of the selection was focused on the idea that whether the last half period was more increase tendency in maximum temperature compared to the whole period or not. Calculations were carried out by using the differences between the second and the whole period. Before using the method, homogeneity test has been applied for maximum temperature data in climatological stations of Turkey. For this purpose, Swed-Eisenhart Run test was used within this study [8]. The Swed-Eisenhart test is a non-parametric test used in determining the randomness or homogeneity of a data set. [9] Data of 165 climatological stations have successes the homogeneity test.

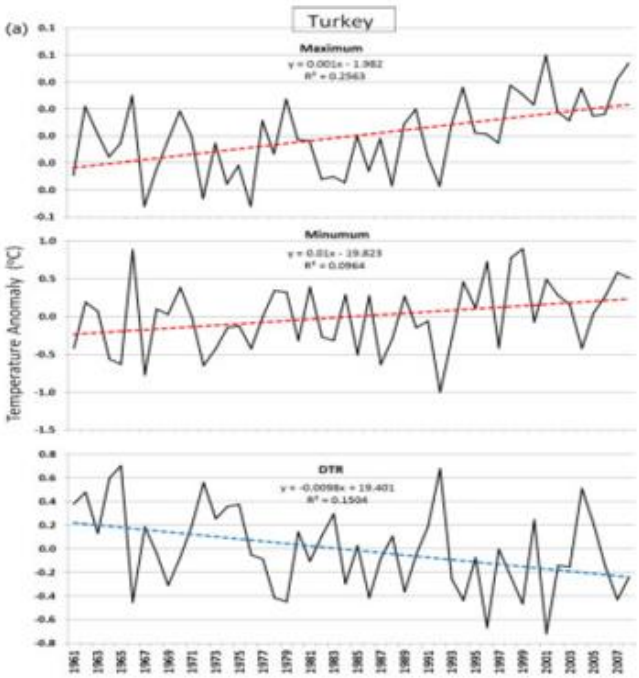
3. GENERAL CLIMATE OVER TURKEY:

Turkey (36–42°N; 26–45 °E) is a region with different climatic features, located at the southeastern part of Europe between Europe and Asia. The total land area is about 780 000 km^2, of which 97% is in Asia and 3% in Europe. The average altitude is 1130 m and gradually increases from the central part of Anatolia to the east. The irregular topographic structure of Turkey is the main reason of climatic diversity. Especially milder climatic conditions are observed in the settlements near the coastal areas, while the conditions in the interior of the country are dry and hot in summer and winter periods. This experienced due to the land shape which is parallel to shorelines. Southern and western regions of the country are under the influence of Mediterranean climate, which cause to hot and dry summers and cool rainy winters in this regions. North of the country (Black Sea region) has a cold and rainy climate. Overall, the Central Anatolia, East Anatolia and South Eastern Anatolia are region of hot and dry summers and harsh and cold winter climate. According to several analysis, a large part of the Anatolia usually has dry sub-humid conditions [10]. Turkey is under the influence of pressure systems showing different characteristics in the summer and winter. In general, country is affected by the Siberian high pressure system from northern and north-east, Icelandic low pressure system from north-west and west and Azores high pressure system from the south and south-west. Besides the cyclonic formations on Mediterranean Sea and Basra through on the east and south east are affecting Turkey. Particularly, Siberian high pressure system and Icelandic low pressure system domain on the country through the winter months and Azores high pressure system and other cyclonic formations (tropical air masses) show itself in the summer months [11].

4. RESULTS AND DISCUSSION:

As seen in Figure 2, there has been a clear increasing trend in extreme temperatures in global land areas. However, so far as Diurnal Temperature Range (DTR)'s are concerned more than 70 % decreasing tendency is observed compared to global land mass since the middle of the twentieth century. On the other hand, for the period 1979-2005, the DTR shows no significant trend since extreme temperature trends for the same period are virtually identical; both with strong warming signal [12,13].

(a)



(b)

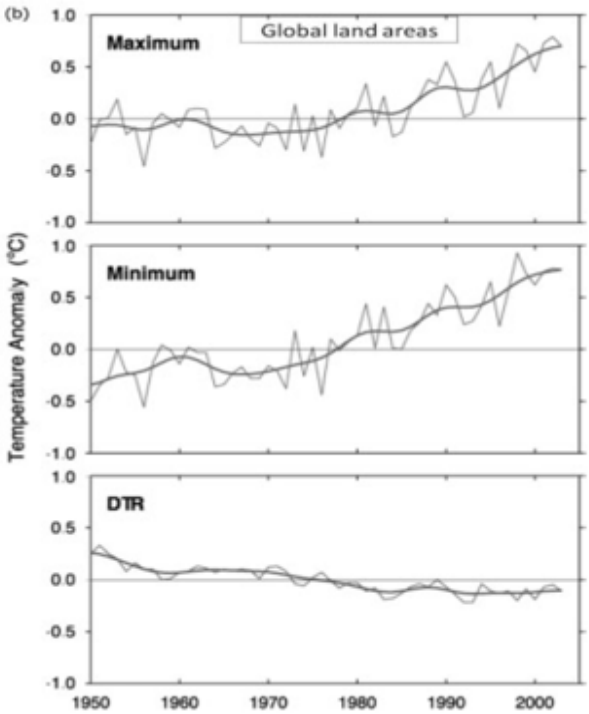


Figure. 2. (a) Time series of the temperature anomalies of the annual mean extremes and (b) DTR [12,13]

4.1. Monthly Results:

Table 1 (a) and (b) represent the number of stations which have increasing, decreasing and no trend in maximum temperature monthly. Increasing trend is more dominant compared to decreasing and no trend.

Table.1. (a) (b). Monthly trend analysis of maximum temperatures.

(a)

Month	Number of Stations With Decreasing Temperature Between 1.0 °C and 1.5 °C	Number of Stations With Decreasing Temperature Between 0.5 °C and 1.0 °C	Number of Stations With Decreasing Temperature Between 0.0 °C and 0.5 °C	Number of Stations With No Temperature Change
January	0	1	22	8
February	0	1	24	12
March	2	11	58	2
April	0	1	16	1
May	0	0	19	2
June	0	3	25	2
July	0	1	27	3
August	0	0	8	1
September	0	0	12	8
October	0	0	15	13
November	0	5	39	21
December	0	4	64	23

(b)

Month	Number of Stations With Increasing Temperature Between 0.0 °C and 0.5 °C	Number of Stations With Increasing Temperature Between 0.5 °C and 1.0 °C	Number of Stations With Increasing Temperature Between 1.0 °C and 1.5 °C	Number of Stations With Increasing Temperature Between 1.5 °C and 2.0 °C	Number of Stations With Increasing Temperature Between 2.0 °C and 2.5 °C
January	96	31	7	0	0
February	89	32	5	2	0
March	67	21	4	0	0
April	77	61	6	3	0
May	78	56	7	3	0
June	98	32	3	2	0
July	84	45	4	1	0
August	53	83	16	3	1
September	89	49	6	1	0
October	105	30	1	1	0
November	85	14	1	0	0
December	64	10	0	0	0

Looking at the all months, it is clearly said that 77% of the stations show positive trends, 18% of the stations show negative trends and 5% of the stations show no trend. Especially, August has the maximum positive trend with the value of 94%. Besides, December has the minimum positive trend with the value of 45%. In general, the number of stations which have 0-0.5 °C maximum temperature increase is more than the other increases dominantly. However; 0.5-1.0°C maximum temperature increase has an important value as a percentage. On the other hand, maximum temperature decreases between 0°C and 0.5°C has a significant value compared to the other intervals.

4.2. Seasonal Results:

4.2.1. Winter Season

Figure 3 reveals the maximum temperature averages of all stations for both study periods in winter season. It is clear that the averages of second period were much higher than first period. Especially in last decade (1999-2008), average of maximum temperature was more than 15.5°C. Figure 4 shows the differences as winter season anomalies between the second period 1985-2008 and the whole period. Most of the stations have positive anomaly values (106 stations). In some stations, anomaly values exceed 1.0°C.

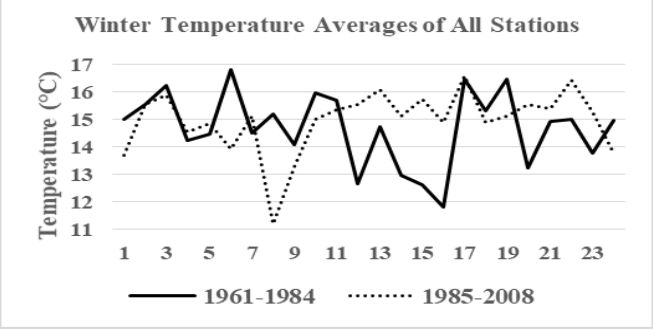


Figure.3. Winter temperature averages for both periods.

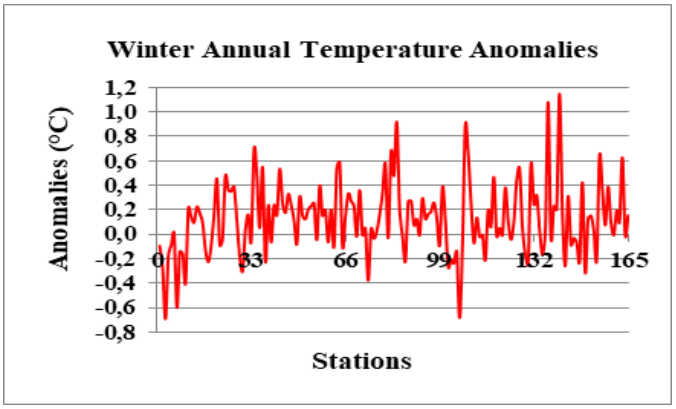


Figure. 4. Winter temperature anomalies of all stations.

4.2.2. Spring Season

Figure 5 indicates the maximum temperature averages of all stations for both periods in spring season. Similar to winter season, averages of second period were higher than the values for first twenty years. Figure 6 shows the differences as spring season anomalies between the second period 1985-2008 and 1961-2008. While there were much more stations that have negative anomaly values, the maximum positive anomaly values were bigger than winter season.

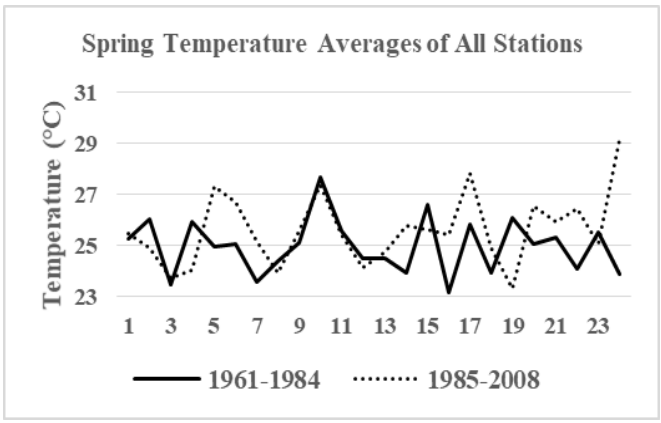


Figure. 5. Spring temperature averages for both periods.

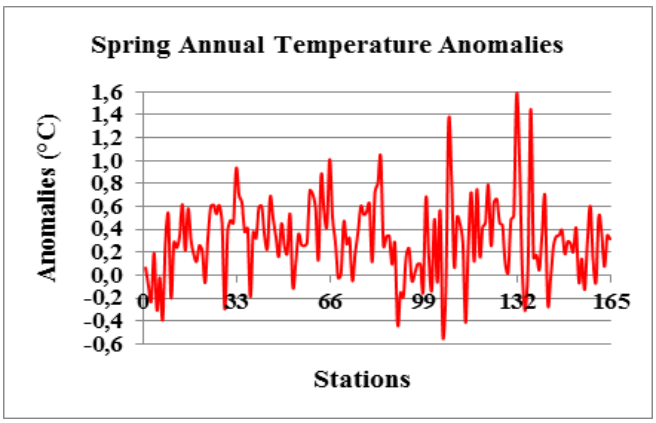


Figure 6. Spring temperature anomalies of all stations.

4.2.3. Summer Season

Figure 7 shows the maximum temperature averages of all stations for both periods in summer season. It is clearly said that the averages of second period was much higher than first period like the other seasons. Especially in last fifteen years, summer maximum temperatures of all stations were more than 34 °C. Figure 8 shows the differences as summer season anomalies between the second period 1985-2008 and the whole period. As seen in the figure, there were too few stations which have negative anomaly values. Most of the

stations had positive anomaly values, in addition; some of the values were more than 1.0 °C.

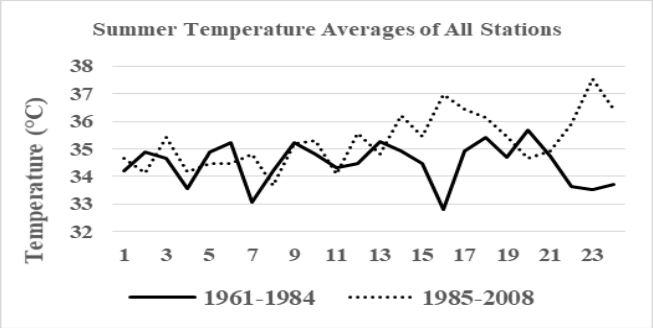


Figure. 7. Summer temperature averages for both periods.

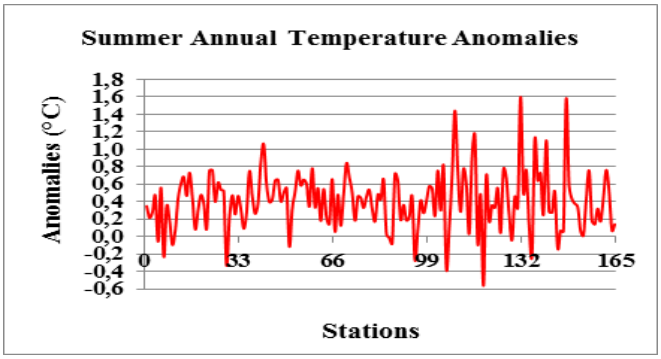


Figure .8. Summer temperature anomalies of all stations.

4.2.4. Autumn Season

Figure 9 indicates the maximum temperature averages of all stations for both period in autumn season. Similar to other seasons, average maximum temperatures of second period were higher than first period. Especially in last decade, nearly all years had average temperatures more than 27°C. Figure 10 shows the differences as autumn season anomalies between the second period 1985-2008 and the whole period. 144 stations had positive anomaly values, with the highest value 1.63.

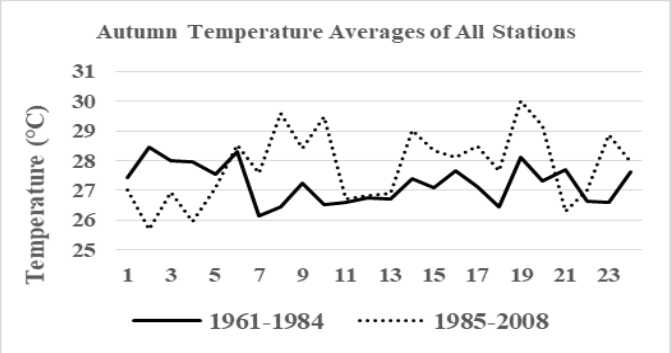


Figure .9. Autumn temperature averages for both periods.

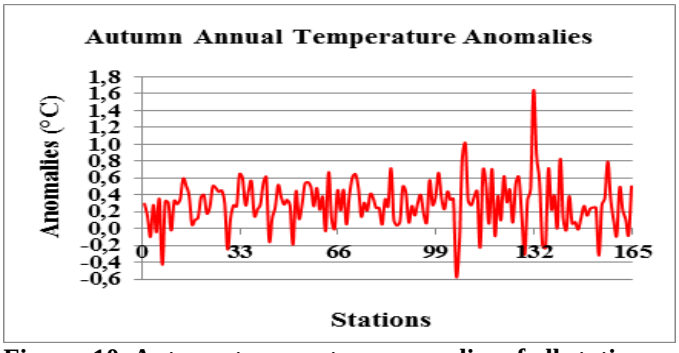


Figure. 10. Autumn temperature anomalies of all stations.

Table 2 represent the number of stations which have increasing, decreasing and no trend in maximum temperatures, seasonally. Increasing trends were more dominant similar to monthly results compared to decreasing trends and no trend tendency. While looking at the all seasons, it can be said that 80% of the stations showed positive trends and 15% of stations showed negative trends. On the other hand, 5% of stations showed no trend. The maximum positive trend was in summer and the minimum positive trend was in winter. The maximum and minimum positive trend showed parallelism with the months which were August in summer and December in winter.

Table.2. (a) (b). Seasonal trend analysis of maximum temperatures.

(a)

Season	Number of Stations With Decreasing Temperature Between 1.0 °C and 1.5 °C	Number of Stations With Decreasing Temperature Between 0.5 °C and 1.0 °C	Number of Stations With Decreasing Temperature Between 0.0 °C and 0.5 °C	Number of Stations With No Temperature Change
Winter	0	3	39	25
Spring	0	1	27	0
Summer	0	1	13	0
Autumn	0	1	14	11

(b)

Season	Number of Stations With Increasing Temperature Between 0.0 °C and 0.5 °C	Number of Stations With Increasing Temperature Between 0.5 °C and 1.0 °C	Number of Stations With Increasing Temperature Between 1.0 °C and 1.5 °C	Number of Stations With Increasing Temperature Between 1.5 °C and 2.0 °C
Winter	86	10	2	0
Spring	92	39	5	1
Summer	93	51	5	2
Autumn	117	21	0	1

5. ACKNOWLEDGEMENT:

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