TIME SERIES ANALYSIS OF MEAN TEMPERATURE DATA IN TURKEY

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ABSTRACT

In this study, the air temperature data obtained from "State Meteorological Service", including 58 stations in Turkey for a period of 45 years between 1950-1994, was investigated. By using the yearly average temperatures, temperature time series were formed for mean temperatures for 58 stations. Gaussian smoothing, Mann-Kendall rank correlation and Wald-Wolfowitz serial correlation tests were applied to these temperature series in order to determine the trends and the abrupt changes in the temperatures.

The results of this study showed that there is a statistically significant cooling trend in 21 stations, warming trend in one station and no trend in 36 stations in Turkey for the mean temperature series. The coldest year observed was 1992 and the warmest year was 1966. The largest negative temperature deviation from the median was observed in Erzurum province with a value of -5 ^{0}C in 1992. The regional changes of the mean temperatures were also investigated. In the Black Sea region, 75% of the stations showed a statistically significant negative trend.

Keywords: Temperature variation, Time series, Gaussian Filtering, Mann-Kendall rank correlation, Wald-Wolfowitz serial correlation

INTRODUCTION

Climate Change is not predictable. By using different climate model calculations, scientist can state that the earth's climate is unstable and the human beings have played an important role on this change. The very rapid development of technology and multiplication of population has brought ecological crises to different regions of the earth. As a result of industrial growth and deforestration, levels of carbon dioxide, methane, CFCs, aerosols and particulate matter have increased in the atmosphere so much that they are changing the earth's climate [5]. According to IPCC [6], "The magnitude and timing of climate change due to all types of activities (natural and man-made activities) will depend on the ultimate concentrations of greenhouse gases and aerosols (particles) and their rates of growth and on the detailed response of the climate system". Greenhouse gases, especially CO_2, have risen considerably after the industrial revolution. The main impacts of the increase in Greenhouse gases on the environment is the global warming (absorption of the solar radiation increases)[13].

The pollution of the air by dust, particulate, fumes and aerosols created either by natural or human activities provides the basis of another important problem. This is the cooling of the earth climate [10]. Approximately one third of incoming solar radiation is reflected back to the atmosphere and the remainder is absorbed by the earth. A positive radiative force tends to warm the surface; but negative one tends to cool the surface [3].

In order to observe this radiation change throughout the years, meteorological air temperatures are studied and this information forms the basis of different scenarios for

climate change. Earth's climate is changing. This means that regional climate is also changing.

Studies related with the determination of variations, trends and/or fluctuations of air temperatures in Turkey are very few. In a study by Türkeş et al. [11] trends in the annual mean air temperature for Turkey as a whole have been concluded that annual mean temperatures has risen by approximately 0.5 ^{0}C between 1930 and the mid-1960s. However, there was a cooling trend in the annual mean temperatures between 1965-1990. Türkeş et al. [12] has mentioned in another paper in 1995 that the analyses indicate some noticeable variations and significant trends in the long term annual mean temperatures. Among the geographical regions, only Eastern Anatolia appears to show similar behaviour to the global warming trends. All the coastal regions, however, are characterized by cooling trends.

The objective of this work is to study the meteorological mean air temperatures in Turkey and see how the regional temperature is changing in this part of the world. In order to achieve this goal, time series analysis of mean temperature data (45 year) will be done and some patterns of variations will be tried to be determined. With this study, the cooling and warming trends of the regional sides over the country will be determined.

STATISTICAL METHODS USED IN THE ANALYSIS OF TEMPERATURE DATA

Data, which are obtained from the observations of a phenomenon over time, are extremely common and named as **Time Series** [1]. "**Time series**" usually has some fluctuations. These fluctuations can be observed by using the most common way, the statistical interpretations. These statistical interpretations are composed of trends, cycles, persistence, and/or other deterministic forms [7].

In many fields, the data seems to have a normal distribution to a good degree of approximation. But when we have precise measurements, it may be obvious that, we cannot assume a normal distribution. We may be able to say that the distribution is skew or symmetric or has some other characteristics. Due to various circumstances, the suitable methods of inference are defined as non-parametric, or in such cases, as distribution-free [9].

In this study, two-non parametric methods are used. These methods are:

Wald-Wolfowitz Serial Correlation: It is a non-parametric method and used to determine the randomness against the serial correlation or the abrupt change in series (Sneyers, 1990).

Mann-Kendall Rank Correlation: It is again a non-parametric test used to demonstrate the possible existence of a trend [8].

In addition these methods, Gaussian Filtering or Smoothing is used to show the variations and/or trends graphically[7].

METHODOLOGY AND ANALYSIS

There are 85 meteorological stations making temperature observations in Turkey. However, only the temperature data obtained from 58 stations between the years 1950 and 1994 have been found to be suitable for this study. The locations of these 58 stations are shown on the map given in Fig. 1. Distributions of the stations within geographical regions are shown below in Table 1.

Construction of the Database: Monthly mean average air temperature data (between 1950-1994) were calculated for each station by using the daily data obtained from the "State Meteorological Service" for 58 stations. **Median** temperatures for each station were also calculated for the time period of 45.

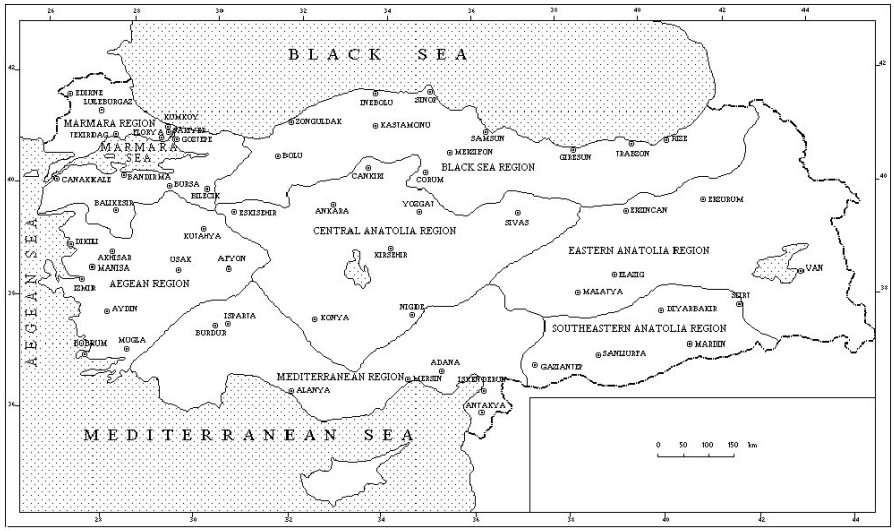


Figure 1. Meteorological stations in Turkey.

Completion of the Missing Data by Regression Analysis: The missing data in the monthly temperature records were completed by using "Linear Regression Analysis" method. First step is to match the station with a nearby station. During matching the stations, "both stations" have to be in the same climate region and at the same elevation. The monthly observed value from a nearby station of which its temperature records is complete is used to estimate the temperature data for the station which has some monthly temperature data missing. Finally, yearly average data for each station are calculated by using the monthly data. Also, the temperature data analysis of the stations should have a correlation coefficient greater than 0.9 and R-squared value equal to or greater than 98% [4].

Statistical and graphical methods: As we have mentioned before, time series usually has some fluctuations. These fluctuations can be observed by using the most common methods, the statistical interpretations and the graphical methods. In order to show the variations and trends in the obtained temperature series, nine-point Gaussian filter was used to smooth the series. After Gaussian filtering, Wald-Wolfowitz serial correlation test and Mann-Kendall rank correlation tests were used. The first test was used to determine the randomness or the abrupt change in series; but the second one was used to detect any possible increasing or decreasing trend in the temperature series.

In order to show the deviation of the yearly mean temperatures from the median temperature, Krigging method [2] was used. A tendency of five year grouping has been observed in the variations after Gaussian Smoothing has been done on the data. Therefore, the average of five years deviations of the yearly average from the median temperature has been calculated and these values were used to prepare temperature deviation maps by Krigging method. The maps were prepared by using Surfer 5.0 and Grapher 1.03 programs.

COMMENTS ON THE ANALYSIS OF MEAN TEMPERATURE DATA

The main goal in this study is to show the variations and trends in mean air temperatures. Yearly average temperatures versus time for each station were plotted to see the changes in temperature. One of these plots is given in Fig. 2. If the station Erzurum is taken as an example (Fig. 2) it is seen that the yearly average temperatures show fluctuations throughout the 45 year period. Gaussian filtering method was used to identify the trend by looking at these fluctuating data. The solid line passing through the fluctuating data on the first plot of

Erzurum shows the Gaussian filtered temperature series. For example, there is a decreasing trend in annual mean temperatures after the 1985.

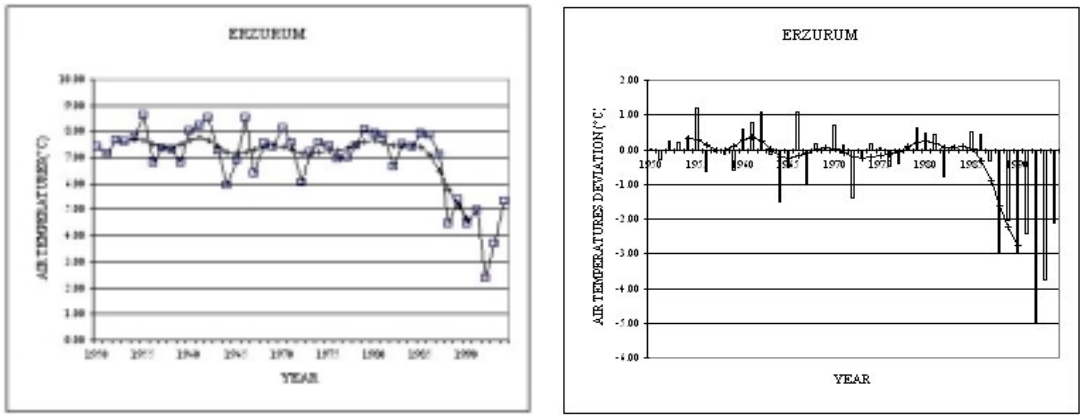


Figure 2. Annual mean air temperatures and temperature deviations from median of Erzurum station between 1950-1994.

Regional Temperature Variations: In order to comment on any trend in temperature data; increasing, decreasing or no change; **Mann-Kendall** rank correlation method was used. According to the results of this test, for **mean temperature series**, (see Table 1), 21 stations showed statistically significant negative trend. Only one series (Adana station) showed statistically significant positive trend. The other 36 stations did not show any significant trend. It means that there is a cooling in (36%) less than half of the stations. The highest negative trend was observed in Lüleburgaz. Then comes İnebolu, Merzifon, İskenderun and Çorum in decreasing order.

Table 1. The results of Mann-Kendall test and Wald-Wolfowitz.

REGIONS	Total Number of Stations	Trends due to Mann-Kendall test			Serial correlation due to Wald-Wolfowitz test	
		-	+	NO	YES	NO
Black Sea	12	9	-	3	-	12
Marmara	11	4	-	7	1	10
Aegean	10	1	-	9	-	10
Mediterranean	7	2	1	4	1	6
Central Anatolia	8	3	-	5	-	8
Eastern Anatolia	5	2	-	3	1	4
Southeastern Anatolia	5	-	-	5	-	5
TOTAL	58	21	1	36	3	55

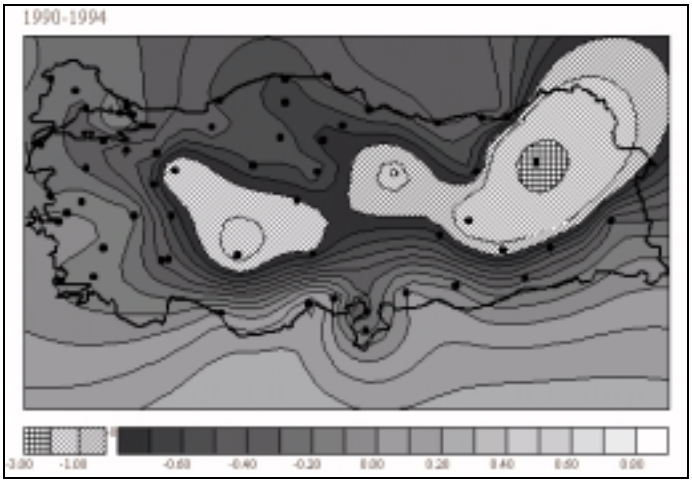
+, Increasing trend; -, Decreasing trend; NO, No trend (Mann-Kendall).
NO, No serial correlation (or abrupt change) in series; YES, Random (Wald-Wolfowitz).

The largest abrupt change confirmed with the Wald-Wolfowitz test in the mean temperature series occurred in Erzurum with a sampling value (u(r)) of 2.83. If we look at the temperature deviations given in Fig. 2, the largest negative temperature deviation of the mean temperature from the median was observed in Erzurum with a value of -5 ^{0}C in 1992.

The number of stations in each region according to the results of tests is given in Table 1. According to the Mann-Kendall Test, warming trends is symbolized with positive sign (+)

and cooling trends is symbolized with negative sign (-). Analysis of the Mann-Kendall results in the **Black Sea region** reveals that 9 out of 12 stations (75%) show statistically significant negative trend for the mean temperatures. This means that in most of the stations in this region, a cooling is observed. In **Marmara region**, 4 out of 11 stations (36%) has shown a cooling trend. The rest of the stations (7 stations) have not shown any statistically significant trend. In **Central Anatolia** region, the number of stations showing a statistically significant negative trend is 3 out of 8 (37.5. In **Eastern Anatolia region**, results show that 2 out of 5 stations (40%) give a statistically significant negative. In the **Mediterranean region**, the number of stations showing a statistically significant negative trend is 2 out of 7 (28%). The **Aegean region** shows a statistically significant negative trend for only 10% of the stations. In the **Mediterranean region**, only 14% of the stations (i.e., only one station) has shown a statistically significant positive trend. The other stations which are not mentioned above do not show any cooling or warming trends.

Temperature Variations in Turkey: In Turkey, a tendency of five year grouping has been observed in the variations of the mean temperature data. Therefore, the average of five years deviations of the yearly average from the median temperature has been calculated and these values were used to prepare temperature deviation maps. In these maps, there are not instantaneous variations in mean temperatures until the year of 1990. But between 1990-1994, the variations can be easily observed for some stations in all types of temperature data (Figure 3). After 1990, especially Erzurum, Elazig, Diyarbakir, Sivas, Eskisehir and Konya stations showed very high cooling almost 2 to 3 ^{0}C deviation from the median. Although, inland stations showed cooling trends, some stations, especially the coastal stations, in Marmara, Mediterranean and Aegean regions showed warming trends.



Temperature deviation from median

Figure 3. The map of "Krigging Method" due to 5 year mean temperature (deviation from median) averages.

CONCLUSIONS

This study has shown that there are regional changes in the mean temperatures in Turkey for a period of 45 years between 1950-1994. The coldest year observed was 1992 and the warmest year was 1966. The largest negative temperature deviation from the median was observed in Erzurum province with a value of -5 ^{0}C in 1992. After 1990, especially Erzurum, Elazig, Diyarbakir, Sivas, Eskisehir and Konya stations showed very high cooling almost 2 to 3 ^{0}C deviation from the median. 21 stations showed statistically significant negative trend.

Only one series (Adana station) showed statistically significant positive trend. The other 36 stations did not show any significant trend. The coastal stations showed positive deviation from median (i.e., warming trends) between 1990-1994.

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