TREND ANALYSIS OF ANNUAL MEAN TEMPERATURE DATA USING MANN-KENDALL RANK CORRELATION TEST IN CATALCA – KOCAELI PENINSULA, NORTHWEST OF TURKEY FOR THE PERIOD OF 1970 – 2011

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Abstract
The study area, Catalca-Kocaeli Peninsula was located on Marmara Region, northwestern of Turkey. Due to the industrialization, transportation and job opportunities excess and adequacy of education and health services, the majority of the population of the Marmara Region is located in the Catalca-Kocaeli peninsula. But in recent years, population growth and urbanization have warming effect on climate in the research area.

***The main objective of this study is to** examine the trend analysis of annual mean temperature from 1970 to 2011. Trend becomes the most commonly used technique to detect temperature variability in regional and local basis. In this study Mann–Kendall Rank Correlation Test was applied to annual mean temperature data from stations located in Catalca-Kocaeli Peninsula to determine the existence and significance of trends, and the years in which changes in the trends started. In order to discuss the trends of annual mean temperature, the annual Mann–Kendall statistics of temperature are illustrated in graphics with MATLAB software.*

Keywords: *Trend analysis, Annual mean temperature, Mann-Kendall trend test, Catalca-Kocaeli Peninsula, Turkey.*

Introduction

Catalca – Kocaeli Peninsula is located at the north-eastern part of Turkey (Figure 1). The research area has the most populated cities which names are İstanbul, Kocaeli and Sakarya. According to the database of Turkish Statistical Institute (TurkStat, 2012) Sarıyer (Istanbul) and Kocaeli have the most population growth between 1970 – 2011 period with 323 % and 316 % rate of increase. (Table 1, Figure 2). Due to the industrialization, transportation and job opportunities excess

and adequacy of education and health services, the majority of the population of the Marmara Region is located in the Catalca-Kocaeli peninsula.

Significant changes in global climate are observed in the past few decades. When global-scale temperature are increase, this situation also affects Turkey (Ustaoglu, 2011). It is known that the increasing concentration of greenhouse gases in the atmosphere which caused by human activity, means a relatively new and serious threat of abrupt climatic change (Tabari et al., 2012). Urbanization makes significant changes in the surface parameters which have the potential to change the local climate in cities (Ezber et al., 2007). Population growth and urbanization have warming effect on climate of research area.

To determine the warming effect, Mann Kendall Rank Correlation method applied to the time series of annual mean temperature to detect trends and abrupt changes in the time-series over the period 1970–2011. The principles of this test have been largely described by Sneyers (1990) and it was used in several climate studies in Turkey (Turkes, 1996, Kadioglu, 1997, Ezber et al., 2007).

Figure 1: Location map of Catalca – Kocaeli Peninsula.

Table 1: Population growth in Catalca – Kocaeli Peninsula for the period between 1970 - 2011 (TurkStat, 2012).

	1970	1975	1980	1985	1990	2000	2010	2011	% (1970 - 2011)
Sarıyer	67902	85262	117659	147503	171872	242543	280802	287309	323

Bakırkoy	341743	560857	882505	1238342	1328276	208398	219145	220663	-35
Kadıkoy	241593	362578	468217	577863	648282	663299	532835	531997	120
Kartal	168822	187105	213839	272546	311532	407865	432199	440887	161
Sile	19427	18648	20424	19310	25372	32522	28119	28847	48
Kocaeli	385408	477736	596899	742245	936163	1206085	1560138	1601720	316
Sakarya	459052	495649	548747	610500	683061	756168	872872	888556	94

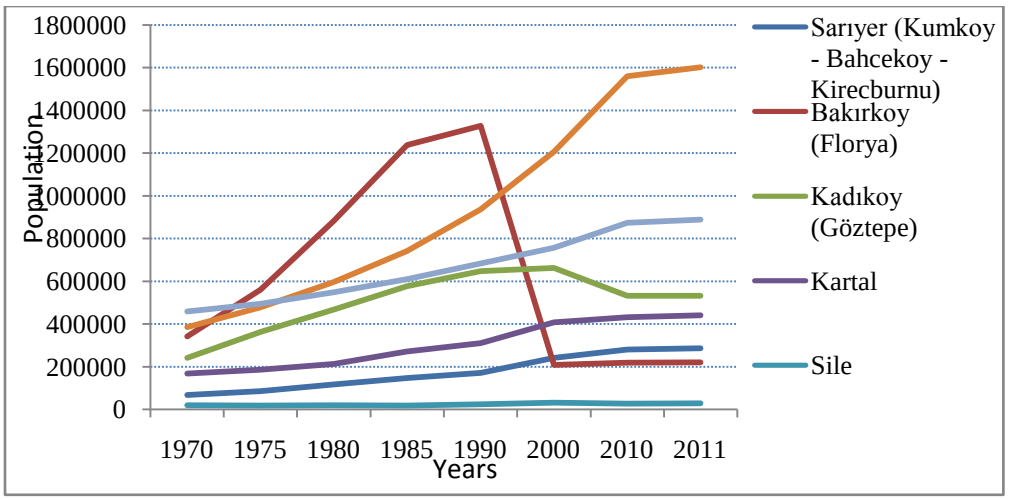


Figure 2: Population growth in Catalca – Kocaeli Peninsula for the period between 1970 - 2011.

Data

Annual mean temperature of meteorological stations of the Turkish State Meteorological Service were used between the period 1970 – 2011. While Kumkoy, Kirecburnu, Florya, Goztepe, Sile, Kocaeli and Sakarya meteorological stations have the same period between 1970- 2011, Bahcekoy and Kartal have the 1970 – 2004 period. Altitude of meteorological stations are around between 30 and 130 meter (Table 2).

Table 2: Characteristics of annual mean temperature of meteorological stations.

Station name	Latitude	Longitude	Altitude (m)	Period
Kumkoy	41,25	29,03	30	1970 - 2011
Kirecburnu	41,17	29,04	58	1970 - 2011
Bahcekoy	41,17	28,94	130	1970 - 2004
Florya	40,98	28,75	36	1970 - 2011
Goztepe	40,97	29,08	33	1970 - 2011
Kartal	40,9	29,18	28	1970 - 2004
Sile	41,18	29,61	31	1970 - 2011
Kocaeli	40,78	29,93	76	1970 - 2011
Sakarya	40,78	30,42	31	1970 - 2011

Methodology

In this study we used Mann Kendall Rank correlation test. The rank-based non-parametric Mann–Kendall statistical test has been commonly used to assess the significance of trends in climatic time series such as temperature and precipitation. The main reason for using non-parametric statistical tests is that compared with parametric statistical tests, the non-parametric tests are thought to be more suitable for non-normally distributed data, which are encountered in climatic time series (Yue et al., 2002). The implementation of the method is realized by writing a code using MATLAB.

Mann Kendall Rank correlation method are as follows:

“In the Mann-Kendall test, for each element xi (i= 1 , . . . , n) of a series yi of length n, ni is the number of elements j which precede i (i >j) such as xi > xj. The trend statistic t of the test is computed as follows:

$$t = \sum_{n}^{i} ni$$

The distribution of t, under the null hypothesis, is practically a normal distribution with the average and the variance given by the following expressions:

$E\ (t) = \frac{n(n-1)}{4}$ and $var\ (t) = \frac{n(n-1).(2n+5)}{72}$

The reduced statistics of t he test, given by |u(t)|, is thus compared to a normal distribution law.

$$u\,(t) = \frac{(t - E\,(t))}{\sqrt{var(t)}}$$

The null hypothesis can, therefore, be rejected for high values of |u(t)|, this being the probability α1 of rejecting the null hypothesis when it is derived from a standard normal distribution table:

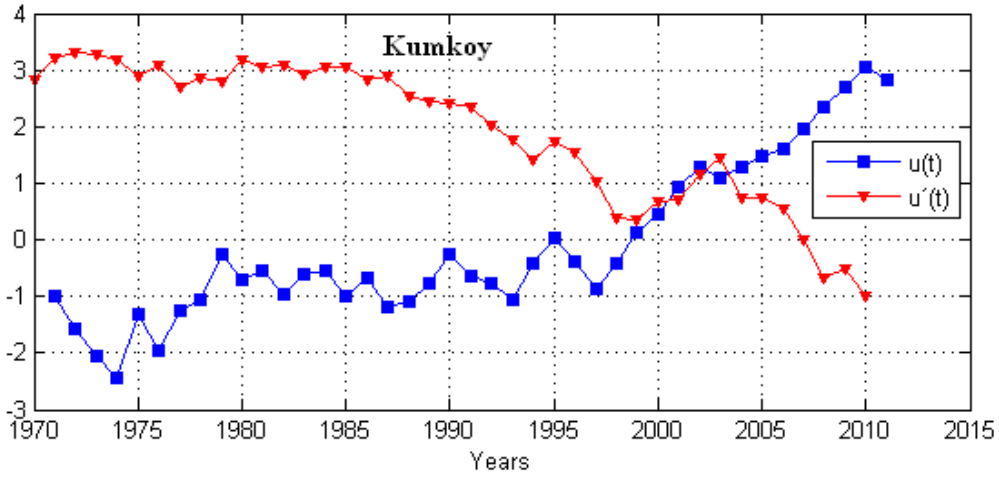
$$\alpha 1 \; = P\,(|u| > |u(t)|)$$

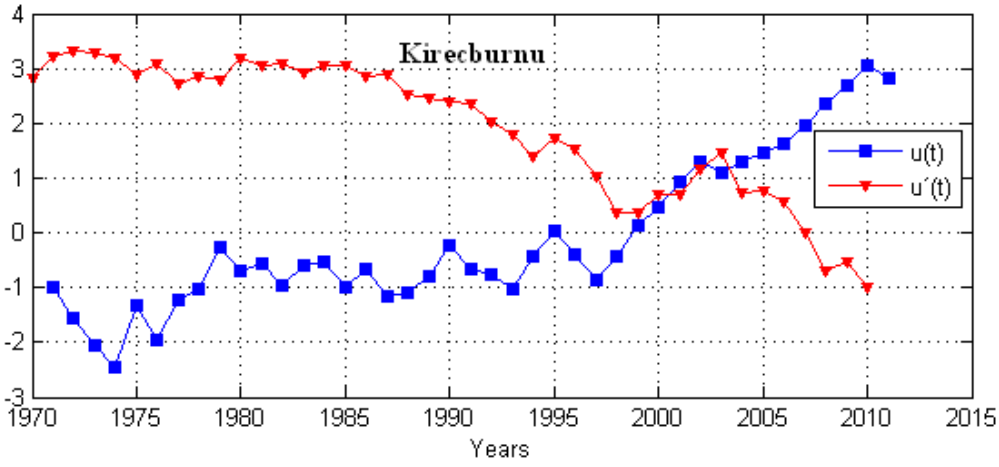
The Mann-Kendall test consists in calculating two series of statistical values, one from the beginning of the series, the second from the end. These series are shown in the form of two curves respectively called the direct curve (ui) and the backward curve (u´i). A trend is significant when the curve ui exceeds the 5% threshold, i.e. when |ui | > 1.96. Significance of trends were evaluated at the 0.05 levels. Sneyers (1990) demonstrated the usefulness of this test, using its direct progressive and backward forms, for identifying the intervals in which trends are most pronounced, and trend turning points and/or climate shifts. The point which marks the beginning of the change corresponds to the intersection between the direct curve and the backward curve, (u´i) . Graphically, the backward and direct curves are often confused when there is no significant trend in the series. When values of u(t) are significant, one concludes to a rising or decreasing trend, for u(t) > 0 or u(t) < 0, respectively (Samba and Nganga, 2012)".

Dıscussıon and Results

In Mann-Kendall application we used 35 years data (n values) for Bahcekoy and Kartal, 42 years data for Kumkoy, Kirecburnu, Florya, Goztepe, Sile, Sakarya and Kocaeli. Figure 3 and Table 3 show the results of annual mean temperature trends of meteorological stations in Catalca – Kocaeli Peninsula. Table 3 shows the results of the Mann–Kendall test applied to the annual mean temperature time series for all stations. All stations display increasing trends. Both Florya and Goztepe have high Mann–Kendall values (3.9 and 3.6 respectively), which indicate significant trends at 95% (1.96) confidence level. Sakarya (3.3), Kumkoy (2.8), Kirecburnu (2.5), Sile (2.4) and Kocaeli (2.3) have significant increasing trend. Bahcekoy and Kartal statistically have no trend. According to this test, the trend in annual mean temperatures is significant at the 95 % statistical confidence level and the trend started from the early 1990s. An increasing in the annual mean temperature after 1994 in the research area because of the population growth and the urbanization effect. We obtained the population results analysing the raw data (Table 1, Figure 2) (TurkStat, 2012). Figure 3 show that the change points in the trends (at 95% level of significance) of these time series over the 42 year period. When we look at the intersection between the direct curve u (t) and the backward curve u´(t) for all

stations, it is seen that the earliest change was started at Florya station with increasing trend in 1994. After that, respectively, Sile - 1998; Goztepe - 1999; Kumkoy, Kirecburnu and Kocaeli - 2002; Sakarya - 2004 with increasing trend. The analyses indicate that the mean annual temperature records in Catalca – Kocaeli Peninsula have a warming trend after the year of 1994. These trends in annual mean temperatures are statistically highly significant.


Kumkoy
u(t)
u´(t)
Years


Kirecburnu
u(t)
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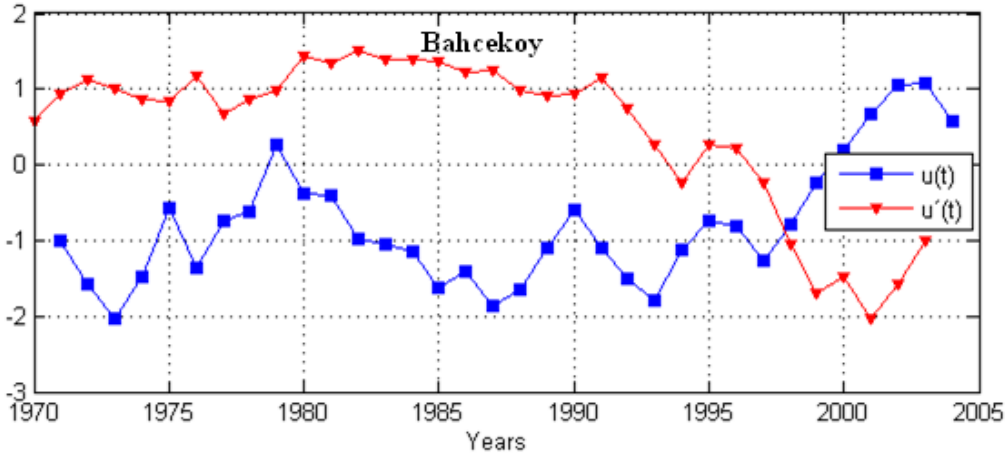
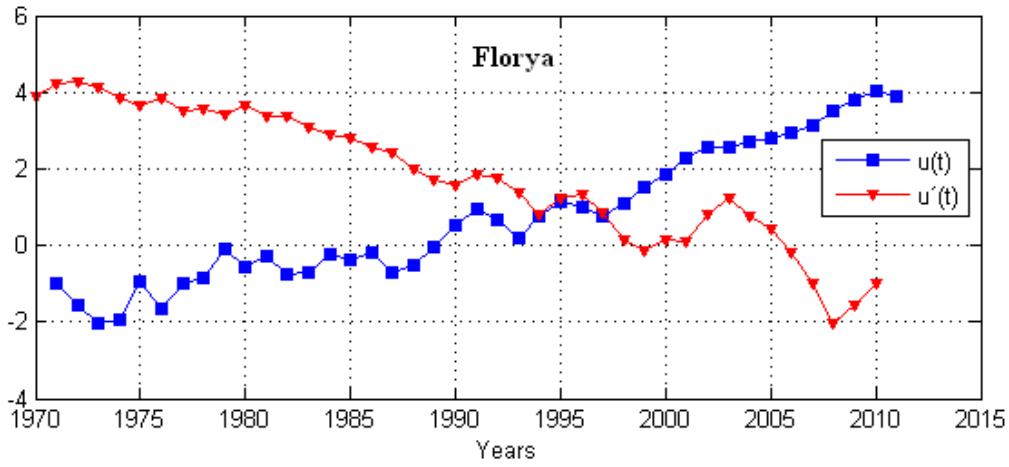
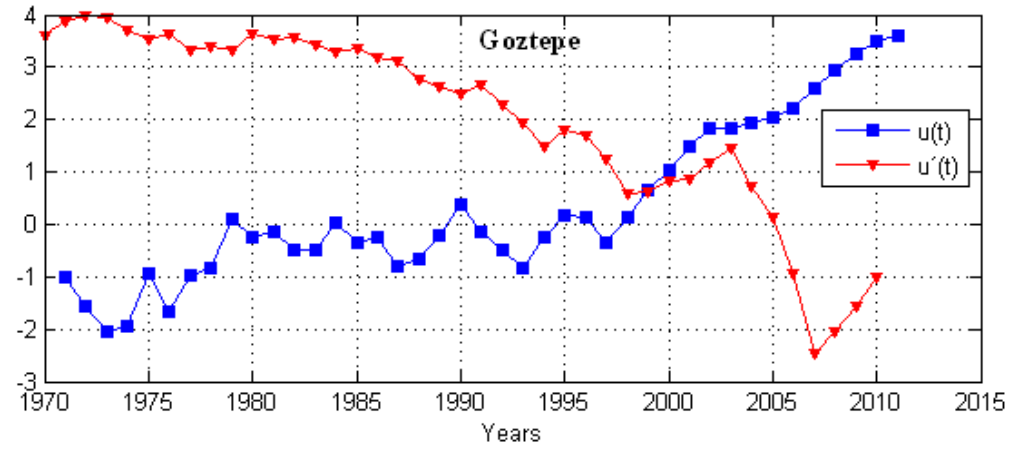
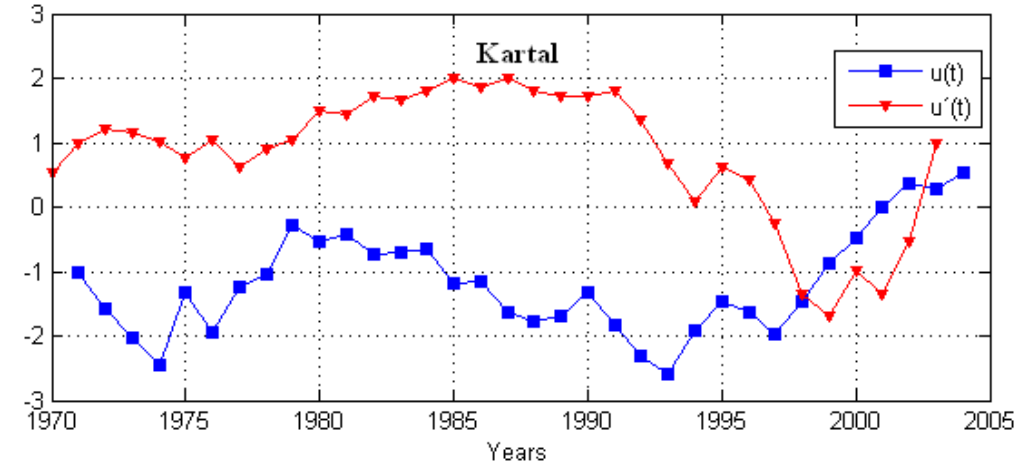
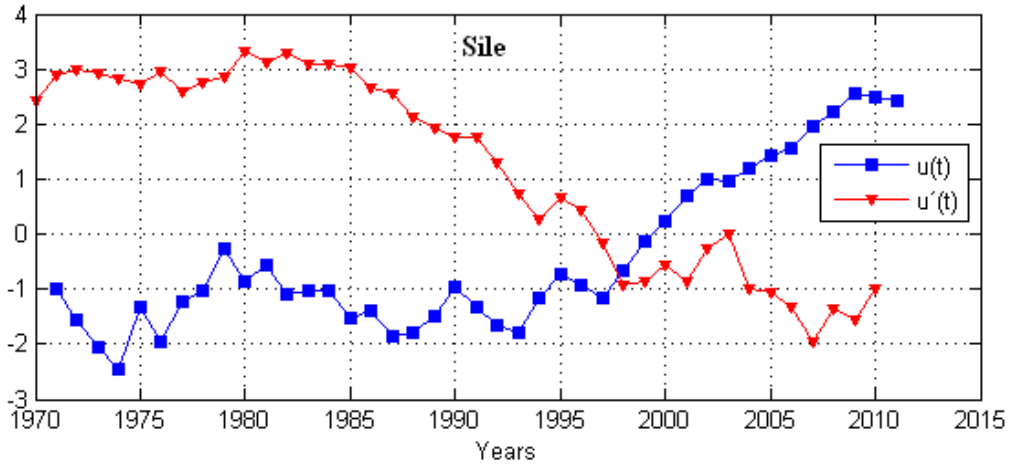
Years

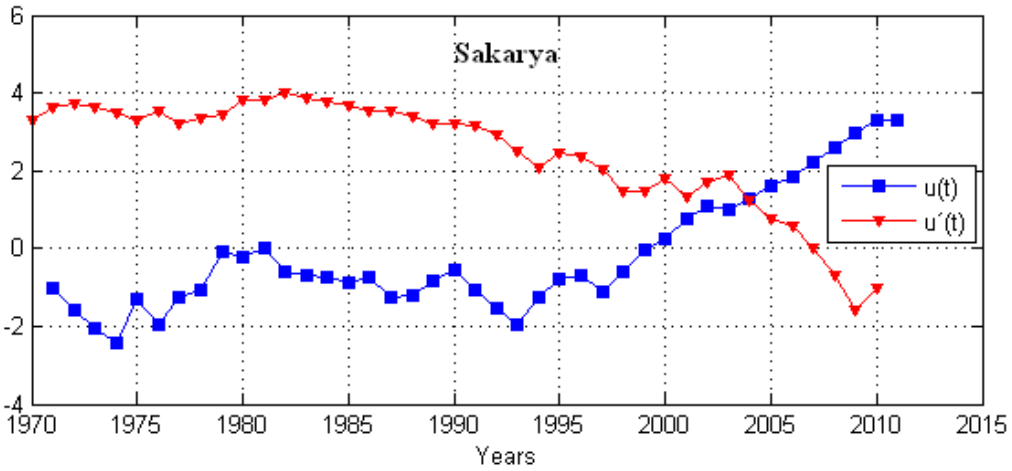

Bahcekoy
u(t)
u´(t)
Years


Florya
u(t)
u´(t)
Years


Goztepe
u(t)
u´(t)
Years


Kartal
u(t)
u´(t)
Years


Sile
u(t)
u´(t)
Years


Sakarya
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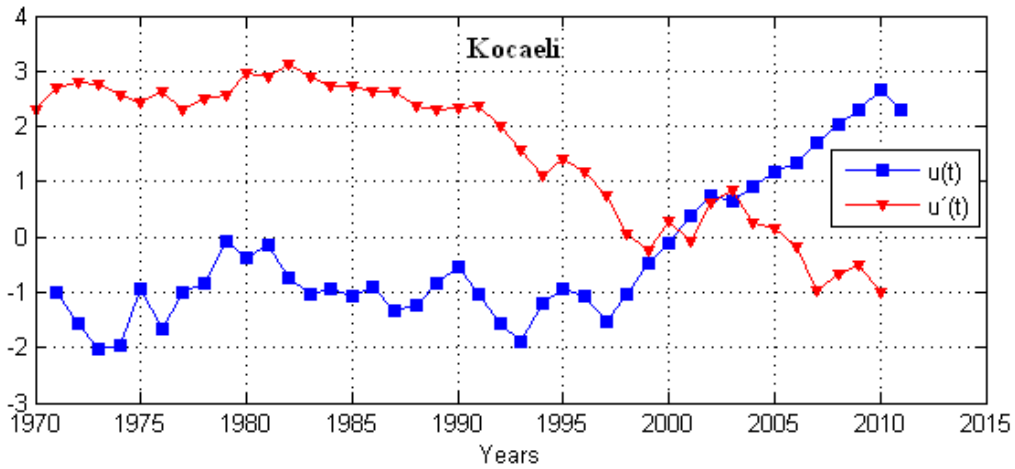
Kocaeli
u(t)
u´(t)
Years

Figure 3: Results of Mann – Kendall Rank Correlation Test of meteorological stations in Catalca – Kocaeli Peninsula between the period of 1970 – 2011. In figures, u(t) values are represented as blue lines, u´(t) values are red lines.

Table 3: Mann–Kendall statistics from the analysis of time series of annual mean temperature data from meteorological stations in Catalca – Kocaeli Peninsula for the period between 1970 - 2011 (Statistically significant numbers are marked bold and underlined).

		Mann - Kendall Rank Correlation Trend Test			
Station name	**Time Series**	**u (t)**	**Trend (at 95% level of significance)**	**Trend year**	**n values**
Kumkoy	Tmean	**2,8**	Increasing	2002	42
Kirecburnu	Tmean	**2,5**	Increasing	2002	42
Bahcekoy	Tmean	0,5	No trend	1998	35
Florya	Tmean	**3,9**	Increasing	1994	42
Goztepe	Tmean	**3,6**	Increasing	1999	42
Kartal	Tmean	0,6	No trend	1998	35
Sile	Tmean	**2,4**	Increasing	1998	42
Kocaeli	Tmean	**2,3**	Increasing	2002	42
Sakarya	Tmean	**3,3**	Increasing	2004	42

Conclusions

Mann Kendall Rank Correlation method applied to the time series of annual mean temperature to detect trends and abrupt changes in the time-series over the period 1970–2011 in Catalca – Kocaeli Peninsula. The main conclusions from the present analysis as follows:

1.) Mann–Kendall values are significant for all stations (Kumkoy, Kirecburnu, Florya, Goztepe, Sile, Kocaeli and Sakarya) except for Bahcekoy and Kartal. Bahcekoy and Kartal statistically have no trend.
2.) According to this test, the trend in annual mean temperatures is significant at the 95 % statistical confidence level and the trend started from the early 1990s because of the population growth and the urbanization effect.
3.) The intersection between the direct curve u(t) and the backward curve u´(t) for all stations, it is seen that the earliest change was started at Florya station with increasing trend in 1994. After that, respectively, Sile - 1998; Goztepe - 1999; Kumkoy, Kirecburnu and Kocaeli - 2002; Sakarya - 2004 with increasing trend.

4.) The analyses indicate that the mean annual temperature records in Catalca – Kocaeli Peninsula have a warming trend after the year of 1994. These trends in annual mean temperatures are statistically highly significant.

Turkey is vulnerable to the anthropogenic-induced climate change as most of the geographical area falls under the Mediterranean climate. Catalca – Kocaeli Peninsula which urbanization and population growth is so intense will be affected by increase in temperature. Thus, conducting such studies is extremely important for improving the certainty of estimates for the future strategic planning.

References

Ezber Y., Sen, O.M., Kindap, T., Karaca, M. 2007. Climatic effects of urbanization in Istanbul: a statistical and modeling analysis Int. J. Climatol. 27: 667–679.

Gaston Samba, G., Nganga, D., 2012. Rainfall variability in Congo-Brazzaville: 1932–2007. Int. J. Climatol. 32: 854–873.

İkiel, C., Ustaoğlu, B., Atalay Dutucu, A., Kılıç, D. E. (2012) "Remote sensing and GIS-based integrated analysis of land cover change in Duzce plain and its surroundings (north western Turkey)", Environmental Monitoring and Assesment, DOI: 10.1007/s10661-012-2661-6, 2012.

Kadıoğlu, M., 1997. Trends in Surface Air Temperature Data Over.Turkey Int. J. Climatol. Vol.. 17, 511–520.

Sneyers, R., 1990, On the statistical analysis of series of observations, Genova, WMO Technical Note143, p.192.

Tabari H., Hosseinzadeh T.P., Ezani, A., Some'e, B.S., 2012. Shift changes and monotonic trends in autocorrelated temperature series over Iran Theor Appl Climatol 109:95–108.

TurkStat 2012, Database of Turkish Population.

http://tuikapp.tuik.gov.tr/adnksdagitapp/adnks.zul?dil=2

Türkeş, M., 1996. Spatial and temporal analysis of annual rainfall variations in Turkey. International Journal of Climatology 16: 1057-1076.

Ustaoglu, B., 2012. Comparisons of Annual Precipitation Gridded and Station Datasets: An example from Istanbul, Turkey, European Geosciences Union General Assembly 2012, 22 – 27 April 2012, Vienna – Austria.

Ustaoglu B., 2011. Türkiye'de A2 Emisyon Senaryosuna Göre Ortalama Yağış Tutarlarının OlasıDeğişimi,", Türk Coğrafya Kurumu Yayınları, Fiziki Coğrafya

Araştırmaları Sistematik veBölgesel. Prof. Dr. M.Y.Hoşgören'in 40. meslek yılı makaleler kitabı, ISBN : Yayın No: 6.

Yue S, Pilon P, Cavadias G., 2002. Power of the Mann-Kendall and Spearman'S rho tests for detecting monotonic trends in hydrological series. J Hydrol 259:254–271.