Chapter 5

Quantification of the Urban Heat Island Under a Changing Climate over Anatolian Peninsula

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/51244

1. Introduction

More than half of the world's population (i.e. approximately 3.5 billion) has been living in urban areas in 2010 and by 2030 this number will rise to almost 5 billion (UNFPA, 2011). In the meantime, global average surface temperature has been increasing significantly: last century saw an approximately 0.7 °C warming (IPCC, 2007; WMO, 2009). Urban growth and climate change are two major forcings on local climate (IPCC, 2007). Urbanization reshapes the surface of the earth causing changes in the energy budget at the ground surface while altering the surrounding atmospheric circulation characteristics leading changes in local climate (Huang et al., 2009; Oke et al., 1992). Urban heat island (UHI) refers to warmer air temperatures observed in urban areas as compared to those over surrounding non-urban regions. When naturally vegetated areas (e.g., grass and trees) are replaced with impervious surfaces having relatively low reflectivity and evapotranspiration rates, additional energy heats the atmosphere causing the phenomena. After sunset, non-urban areas cool more rapidly than urban regions resulting in a temperature differential. The UHI is presented as the difference between temperatures recorded within and outside the urban settlement. It has been suggested that UHI is influenced by population; topography; level of industrialization as well as the regional climate (Oke, 1987; Rosenzweig et al., 2005; Gill et al., 2008; Kolokotroni & Giridharan, 2008).

Anatolian peninsula, (i.e. Asian part of Turkey), is lying in the Eastern Mediterranean, and has seven distinct geographical regions: Eastern Anatolia; Central Anatolia; Black Sea Region; Mediterranean Region; Aegean Region; Marmara Region; and Southeastern Anatolia (Unal et al., 2003; Kindap, 2010). The Aegean and Mediterranean coastal regions have cool rainy winters, and hot moderately dry summers. Mountains along the coast

prevent the Mediterranean influences from extending inland, giving interior of Anatolian Peninsula a continental climate and distinct seasons.

As urbanization rate has increased significantly, UHI has become a significant issue in the Anatolian Peninsula. There have been a few studies focusing on UHI effect over Anatolian Peninsula (Karaca et al., 1995; Tayanc & Toros, 1997; and Ezber et al., 2007). For example, Karaca et al. (1995) investigated the effects of urbanization on climates of two cities, Istanbul and Ankara in the Anatolian Peninsula with varying periods (1912-1992) and reported significant upward trend for the urban temperatures when compared to the rural temperatures in the southern part of Istanbul. Tayanc & Toros (1997) studied 4 urban areas (i.e., Adana, Bursa, Gaziantep, Izmir) suggesting that temperature is more sensitive to UHI than precipitation and their results showed that the Anatolian Region is under a cooling trend after the period ending by 1990. Ezber et al. (2007) used statistical and numerical modeling tools to investigate the climatic effects of urbanization in Istanbul from the period of 1951 to 2004, and they found statistically positive trends in the urban stations of the city. These studies focused on cities individually and have not conducted a comprehensive evaluation of all urban environments in Anatolian Peninsula. The objective of this study, hence, is to quantify the UHI effect of the all major cities (population>1,000,000) with quality meteorological data extending back to 1965. Climate forecasts using a regional climate model output are also analyzed to understand the effect of UHI under a changing climate.

2. Material and methods

2.1. Temperature data

Minimum daily temperature is the primary indicator of UHI (Rosenzweig et al., 2005). We have, therefore, compiled a database of minimum daily temperatures over urban cities in Anatolia. As a first step, we have developed and implemented the following criteria: Urban stations are selected in regions having population over 500,000, and rural stations with population of less than 100,000 (Hua et al., 2007); high quality temperature data (i.e., passes homogeneity test, have representative urban and rural stations); continuous data from 1965 to 2006. After comprehensive evaluation, especially for representativeness, we have identified 8 cities to analyze, a total of 25 meteorological stations (9 urban and 16 rural). These cities are highlighted in Table 1.

Selected cities have significant increase in urban population between 1935 and 2011, are shown in Fig. 1. Ratio of the center population is calculated by dividing the center population (urban districts of the city, not the rural) of the selected cities to the total population of the city. Dark colored bar in the figure is the ratio of the year 1935, and the total bar including the shaded and the dark is the ratio in 2011. For example, in 1935 approximately 50% of Istanbul's population is urbanized, which increased to approximately to 100% in 2011. In 1935, number of cities that have urban ratio of 50% or more was only one (i.e. Istanbul), whereas in 2011 all of the selected cities have urban population ratio of more than 50%.

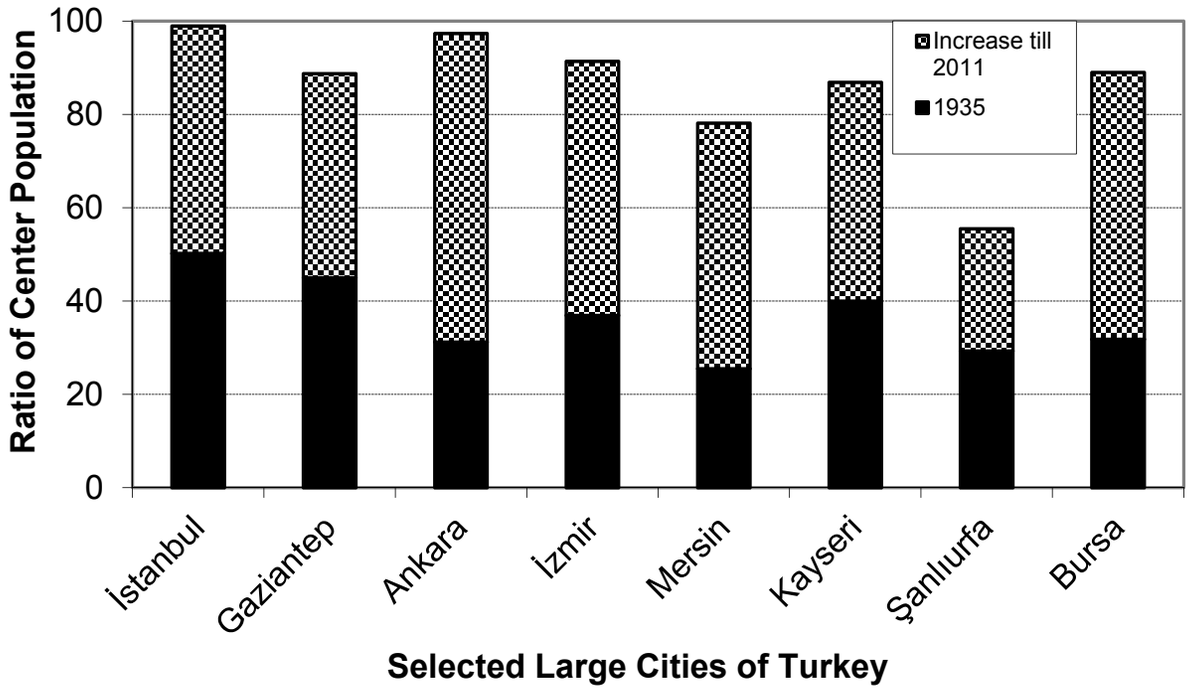


Figure 1. The rate of urbanization in terms of urban over total population (%) in 1935 and 2011

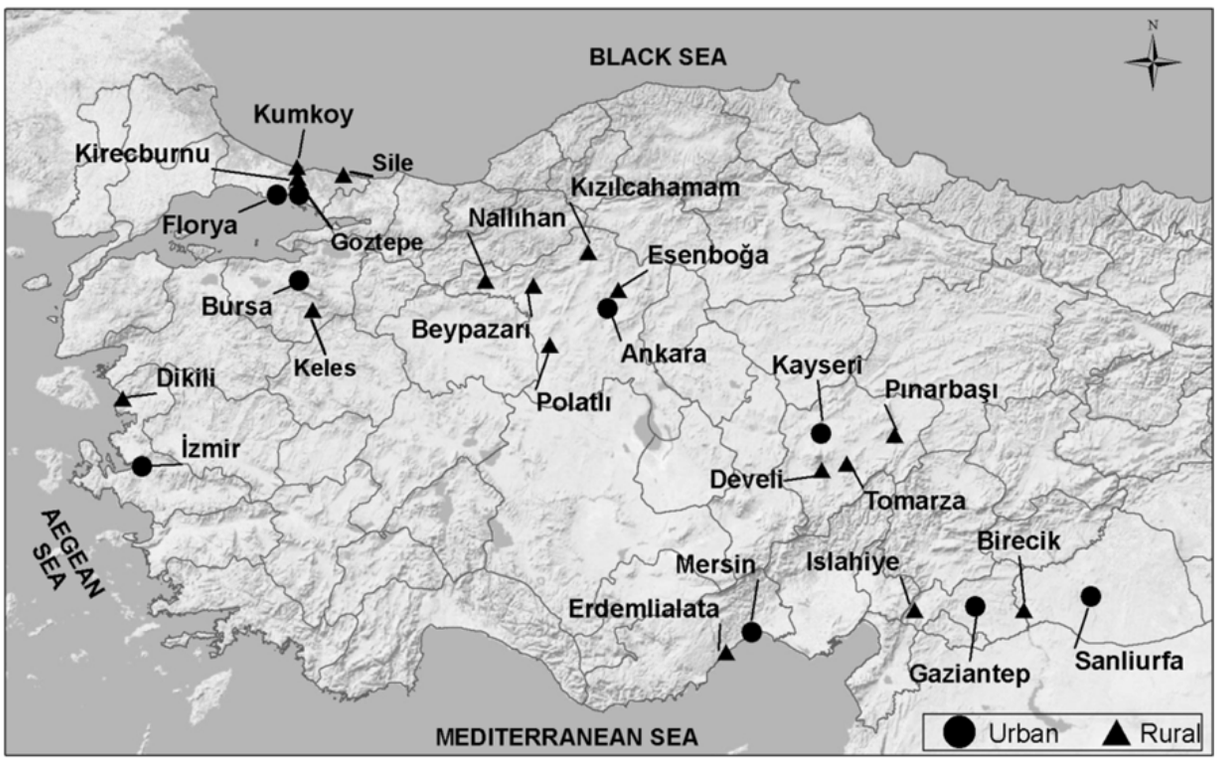


Figure 2. Locations of meteorological monitoring stations

Northern Marmara		Aegean and Western Mediterranean		Black Sea		Central Anatolia		Eastern Anatolia		Southeastern Anatolia		Eastern Mediterranean	
City	**Pop.**	**City**	**Pop.**	**City**	**Pop.**	**City**	**Pop.**	**City**	**Pop.**	**City**	**Pop.**	**ties Pop.**	**Pop.**
İstanbul	13,624,240	İzmir	3,965,232	Samsun	1,251,729	Ankara	4,890,893	Van	1,022,532	Gaziantep	1,753,596	Adana	2,108,805
Kocaeli	1,601,720	Bursa	2,652,126	Trabzon	757,353	Konya	2,038,555	Erzurum	780,847	Şanlıurfa	1,716,254	Antalya	2,043,482
Sakarya	888,556	Manisa	1,340,074	Ordu	714,390	Kayseri	1,255,349	Ağrı	555,479	Diyarbakır	1,570,943	Mersin	1,667,939
Tekirdağ	829,873	Balıkesir	1,154,314	Zonguldak	612,406	Eskişehir	781,247	Muş	414,706	Mardin	764,033	İskenderun	1,474,223
Edirne	399,316	Aydın	999,163	Giresun	419,498	Afyon	698,626	Bitlis	336,624	Malatya	757,930	Kahramanmaraş	1,054,210
Kırklareli	340,199	Denizli	942,278	Düzce	342,146	Sivas	627,056	Kars	305,755	Adıyaman	593,931	Osmaniye	485,357
Yalova	206,535	Muğla	838,324	Rize	323,012	Tokat	608,299	Erzincan	215,277	Elazığ	558,556		
		Kütahya	564,264	Karabük	219,728	Çorum	534,578	Iğdır	188,857	Batman	524,499		
		Çanakkale	486,445	Sinop	203,027	Yozgat	465,696	Ardahan	107,455	Şırnak	457,997		
		Uşak	339,731	Bartın	187,291	Isparta	411,245	Tunceli	85,062	Siirt	310,468		
				Artvin	166,394	Aksaray	378,823			Hakkari	272,165		
				Gümüşhane	132,374	Kastamonu	359,759			Bingöl	262,263		
				Bayburt	76,724	Niğde	337,553			Kilis	124,452		
						Amasya	323,079						
						Nevşehir	283,247						
						Kırıkkale	274,992						
						Bolu	276,506						
						Burdur	250,527						
						Karaman	234,005						
						Kırşehir	221,015						
						Bilecik	203,849						
						Çankırı	177,211						

* Cities highlighted are analyzed in the study

Table 1. Cities with their populations in each climatological region of the Anatolian Peninsula (TUIK, 2012)

2.2. Study area

Regarded by many as the cradle of civilization of the world, the Anatolian Peninsula is located at the confluence of Europe, Asia and Africa. This region has 75 million inhabitants (TUIK, 2012). The population has grown almost 4.7 times between 1935 and 2012, from 16 million to 75 million (TUIK, 2012). Ratio of rural to urban population has changed dramatically especially after 1980s and urban population ratio reached to about 80% in 2010 (Fig. 3). Table 1 lists the cities in each climate regions with their population. Approximately, 74% of the cities have the population between 100,000 and 1 million; 22% between 1 million and 5 million. Only 2 cities are below 100,000, and Istanbul is the only megacity (i.e., the city which has a population of five million or more) in the region having a population of over 13 million. Table 2 gives a classification about the site characteristics of the selected meteorological stations.

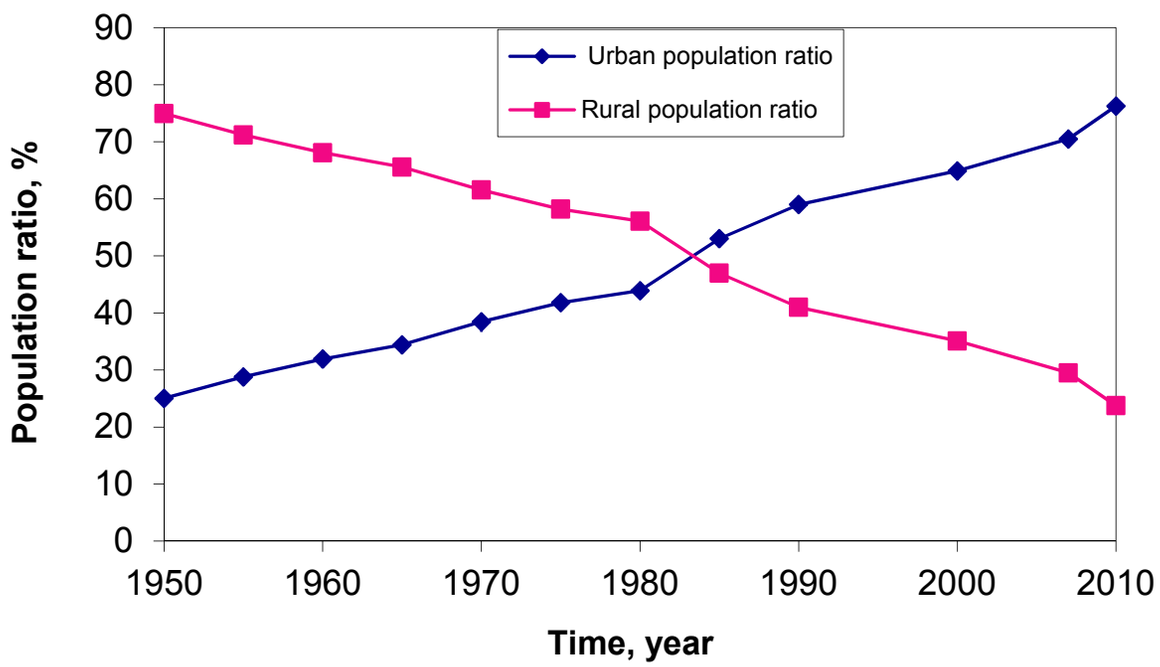


Figure 3. The population ratio of urban and rural parts of the region over total population from 1950 to 2010 (TUIK, 2012)

Station	Latitude	Longitude	Altitude (m)	Land-use	Location and siting
Ankara	39° 57′	32° 53′	891	Urban	In a residential area at the city center on the ground
Polatli (Ankara)	39° 35′	32° 09′	886	Suburban	70 km away from the city center on the ground
Kizilcahamam (Ankara)	40° 28′	32° 39′	1033	Rural	50 km away from the city center on the ground
Beypazari (Ankara)	40° 10′	31° 56′	682	Rural	75 km away from the city center on the ground
Esenboga (Ankara)	40° 07′	33° 00′	959	Urban	At the airport in the city center on the ground
Nallihan (Ankara)	40° 11′	31° 22′	650	Rural	120 km away from the city center on the ground
Bursa	40° 23′	29° 01′	100	Urban	5 km away from the city center at the airport on the ground
Keles (Bursa)	39° 54′	29° 13′	1063	Rural	60 km away from the city center on the ground
Gaziantep	37° 08′	37° 37′	900	Urban	In a residential area at the city center on the ground
Islahiye (Gaziantep)	37° 02′	36° 61′	706	Rural	50 km away from the city center on the ground
Istanbul (Goztepe)	40° 97′	29° 06′	33	Urban	In a residential area at the city center on the ground
Istanbul (Florya)	40° 97′	28° 79′	37	Urban	In a residential area at the city center on the ground
Kirecburnu (Istanbul)	41° 15′	29° 05′	58	Rural	25 km away from the city center on the ground
Kumkoy (Istanbul)	41° 25′	29° 04′	38	Rural	30 km away from the city center on the ground
Sile (Istanbul)	41° 17′	29° 60′	83	Rural	50 km away from the city center on the ground
Izmir	38° 39′	27° 08′	29	Urban	In a residential area at the city center on the ground
Dikili (Izmir)	39° 07′	26° 89′	3	Rural	75 km away from the city center on the ground
Kayseri	38° 77′	35° 49′	1092	Urban	In a residential area at the city center on the ground
Develi (Kayseri)	38° 28′	35° 54′	1180	Rural	40 km away from the city center on the ground
Pinarbasi (Kayseri)	38° 77′	36° 61′	1500	Rural	75 km away from the city center on the ground
Tomarza (Kayseri)	38° 27′	35° 48′	1397	Rural	35 km away from the city center on the ground
Mersin	36° 78′	34° 60′	3	Urban	In a residential area at the city center on the ground
Erdemli Alata (Mersin)	36° 38′	33° 94′	9	Suburban	35 km away from the city center on the ground
Sanliurfa	37° 16′	38° 79′	547	Urban	In a residential area at the city center on the ground
Birecik (Sanliurfa)	37° 02′	37° 96′	345	Rural	65 km away from the city center on the ground

Table 2. Site characteristics of selected meteorological stations

2.3. Urban Heat Island

The UHI effect refers to an increase in urban air temperatures as compared to surrounding suburban and rural temperatures (Oke, 1982; Quattrochi et al., 2000).

UHI effect is defined as:

$$\Delta T_{u-r} = T_u - T_r \tag{1}$$

where T_u is the urban station temperature, T_r is the rural station temperature, $\Delta T_u - r$ is the effect of UHI.

Heat islands develop in areas that contain a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetated and moisture-trapping surfaces (Rosenzweig et al., 2005). In particular, materials such as stone, concrete, and asphalt tend to trap heat at the surface (Landsberg, 1981; Oke, 1982; Quattrochi et al., 2000) and a lack of vegetation reduces heat lost due to evapotranspiration (Lougeay et al., 1996). The addition of anthropogenic heat and pollutants into the urban atmosphere further contributes to the intensity of the UHI effect (Taha, 1997). The pollution created by emissions from power generation increases absorption of radiation in the boundary layer (Oke, 1982) and contributes to the creation of inversion layers. Inversion layers prevent rising air from cooling at the normal rate in urban areas.

Globally average surface warming is projected to increase for the end of the 21st century (2090 to 2099), relative to 1980 to 1999 within the six different scenarios between 1.1 - 6.4 °C (IPCC, 2007). Climate change has the potential to significantly alter the intensity and increase the spatial extent of heat islands in urban environments. As temperature warms, the frequency with which UHI conditions occur could grow (Rosenzweig et al., 2005).

2.4. Mann-Kendall trend test

Trend analysis can be used to assess the climatic variations of the atmosphere and the Mann-Kendall trend test (Mann, 1945; Kendall, 1975) is one of the widely used non-parametric tests to detect significant trends in time series. The Mann-Kendall trend test is not affected by the actual distribution of the data and is less sensitive to outliers rather than parametric trend tests, which are more powerful, but more sensitive to outliers. Therefore, Mann-Kendall test is more suitable for detecting trends in temperature time series, which may have outliers (Hamed, 2008). Climate change can be detected by the Kendall coefficient t (Mann test) and when a time series shows a significant trend, the period from which the trend is demonstrated can be obtained effectively by this test. In a time series, for each element y_i, the number n_i of elements y_j preceding it ($i > j$) is calculated such that $y_i > y_j$.

The test statistic t is then given by,

$$t = \sum n_i, \tag{2}$$

and is distributed very nearly as a Gaussian normal distribution with an expected value of $E(t) = n(n-1)/4$ and a variance of var$t = n(n-1)(2n+5)/72$. A trend can be seen for high values of $|u(t)|$, where,

$$u(t) = \frac{\left[t = E(t)\right]}{\sqrt{\operatorname{var} t}}, \tag{3}$$

This principle can be usefully extended to the backward series and $u_i = -u(t_i)$ can be obtained. The intersection of the $u(t)$ and $u'(t)$ curves denotes approximately the beginning of the trend. This is called the sequential version of the Mann-Kendall test (Goossens & Berger, 1986). If a Mann-Kendall statistic of a time series is higher than 1.96, there is a 95% significant increase in that particular time series. If the result is just the reverse; lower than -1.96, there is a 95% significantly decreasing trend in the series. Also, results between 0.5 and 1.96 indicate increasing, -0.5 and -1.96 indicate decreasing trends, and 0.5 and -0.5 indicate no trend. The Mann-Kendall statistics are then plotted on a map in order to show the spatial distribution of both the significant and non-significant temperature trends in Turkey.

3. Results and discussion

Observation data over the Anatolian Peninsula were analyzed to understand trends in average temperature. As can be seen in Fig. 4a, as of 2009, average temperatures in all 8 cities are higher than temperature in 1960s. For example, average temperature increase in Kayseri, Gaziantep, and Mersin is over 2 °C. Fig. 4b presents anomaly in mean temperatures in Anatolian Peninsula as estimated using gridded dataset obtained by the Climate Research Unit (CRU - TS3.0). The results suggest an increase of 0.5 °C starting in 1990s.

Trends in daily minimum temperatures at individual meteorological stations were investigated with the Mann-Kendall trend test (Mann, 1945; Kendall, 1975). As an example, annual time series of minimum temperatures for the urban stations of Istanbul (Goztepe & Florya) and its sequential version of the Mann-Kendall test graph is presented in Fig. 5. In Mann-Kendall plots, as of 1965, Goztepe station has a minimum temperature of 10 °C, which increased to 11.5 °C in 2006. Similar trend is seen for Florya station. Significance of the trend has been identified by Mann-Kendall statistics where the area above the line passing 1.96 represents the 95% significance level. Both Goztepe and Florya stations show a significant increase starting by mid to late 1990s.

The Mann-Kendall statistic of the annual minimum temperatures for the urban and rural stations are presented in Table 3. In all urban stations, Mann-Kendall statistics suggest statistically significant increase. In rural stations, however, out of 16 stations, 13 stations do not show any significant trend; only 1 of them have statistically significant increase and 2 of them show decreasing trend. After 1990s, the population of Beypazari and Tomarza are on the decline, and this may be the reason for the negative trends in these two rural stations. These results suggest that an additional factor: possibly UHI, is in motion to cause significant increase in minimum temperatures over urban areas. In order to further

investigate this hypothesis, we have studied trends in temperature differences between urban and rural environment for the selected cities.

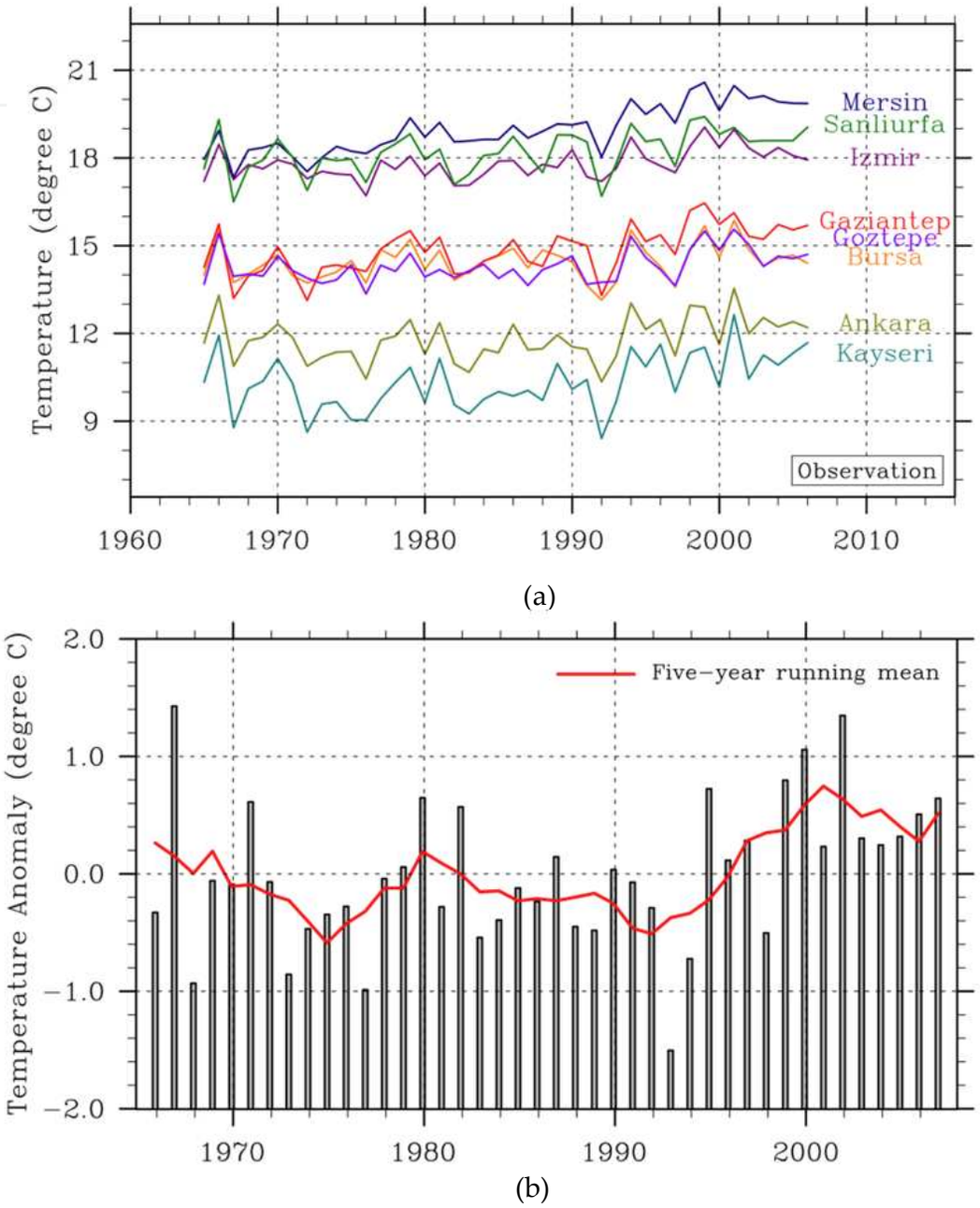
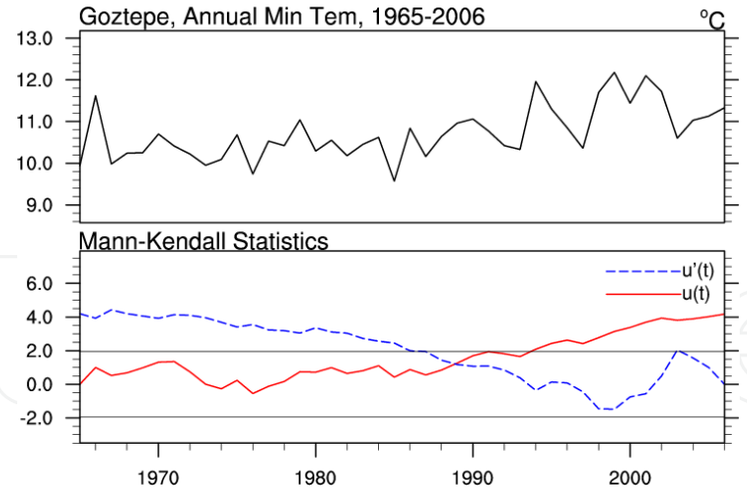
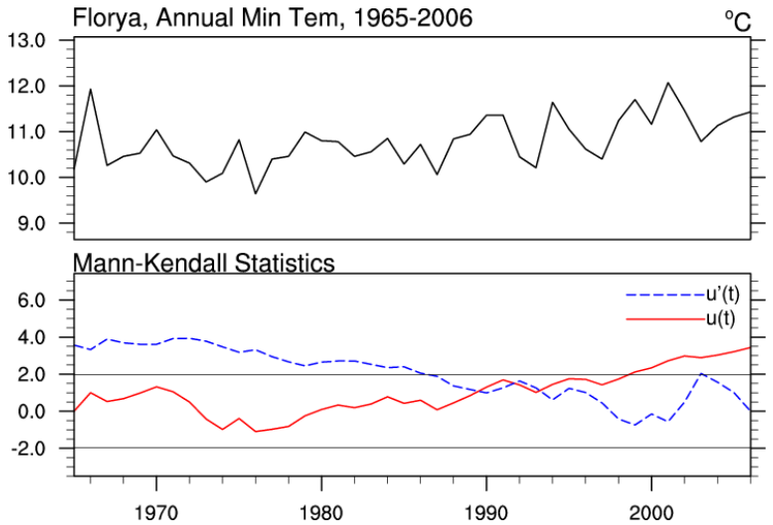


Figure 4. (a) Observation mean temperature variation in large Anatolian Cities and (b) anomaly in yearly mean temperatures in the Anatolian Peninsula from 1965 to 2006



(a)



(b)

Figure 5. The annual time series of minimum temperature for the urban stations of Istanbul and its sequential version of the Mann-Kendall test; a) Goztepe, b) Florya

Urban Station	T_{min} Statistics (1965-2006)
Ankara*	2,93
Bursa*	2,20
Gaziantep*	4,87
Istanbul (Goztepe)*	4,19
Istanbul (Florya)*	3,46
Izmir*	2,61
Kayseri*	5,08
Mersin*	7,06
Sanliurfa*	4,35

(a)

Rural Station	T_{min} Statistics (1965-2006)
Polatli (Ankara)	0,38
Kizilcahamam (Ankara)	0,99
Beypazari (Ankara)	-2,87
Esenboga (Ankara)	0,55
Nallıhan (Ankara)	-0,73
Islahiye (Gaziantep)*	2,18
Kirecburnu (Istanbul)	1,81
Kumkoy (Istanbul)	1,22
Sile (Istanbul)	-0,14
Dikili (Izmir)	1,46
Develi (Kayseri)	-1,51
Pinarbasi (Kayseri)	0,49
Tomarza (Kayseri)	-2,29
Keles (Bursa)	-0,64
Erdemli Alata (Mersin)	1,48
Birecik (Sanliurfa)	0,40

(b)

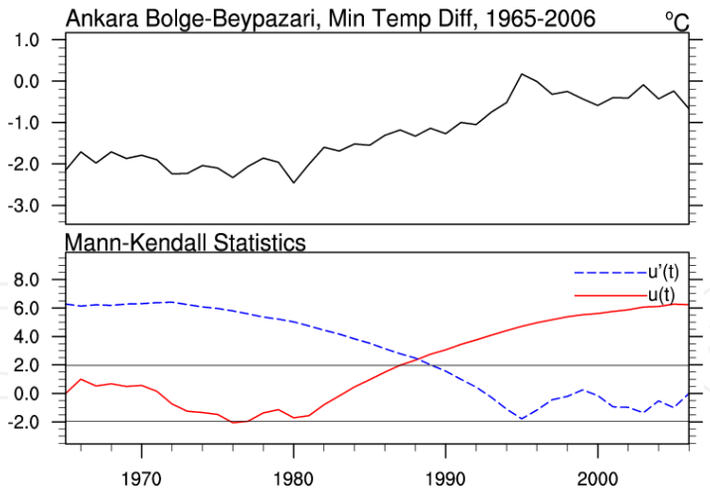
*Shows statistically significant increasing trend

Table 3. Annual minimum temperature statistics of stations; a) urban, b) rural

The Mann-Kendall results of the other urban-rural pairs are given in Table 4. Example of the results are given in Fig. 6. Time series and the statistics for the city of Ankara, the capital of Turkey show strongly increasing warming trend (Fig. 6a). Ankara is the most crowded city of Turkey after Istanbul and located in the center of Anatolia. Because of the migration from rural sites to the center of the city (Fig. 2), Ankara has become a highly populated city, although there is not a significant industrial activity in the area. Eventually, urban-rural pairs of Ankara have high Mann-Kendall statistics over 1.96 (Table 4), which demonstrates the UHI effect in the capital of Turkey.

Bursa, which is located in the south of the Marmara Sea, has a growing population (Fig. 2) with a highly industrialized area, producing the urbanization phenomenon in the city with the human migration to the city like Istanbul. The minimum temperature difference series for Bursa-Keles station pair shows significantly increasing warming trend (Fig. 6b) with a Mann-Kendall statistic of 4.30 (Table 4). The city of Gaziantep is located in the southeastern part of Anatolia and has a growing population like the other large cities in the region and has a developing industry. The Mann Kendall statistics of the urban-rural pair shows a significantly increasing trend (Fig. 6c) with 5.82.

Istanbul and Bursa are the cities located in the north-west of Anatolia. This region is the most industrialized part of the country. Istanbul is the largest city of Turkey with over 13 million population (TUIK, 2012). Due to the cultural and financial features of the city, migration is generating the urbanization and making the Istanbul a mega city. It is located on the Bosporus and extends both on the European and Asian sides; therefore to investigate


Ankara Bolge-Beypazari, Min Temp Diff, 1965-2006
°C
1.0
0.0
-1.0
-2.0
-3.0
Mann-Kendall Statistics
u'(t)
u(t)
8.0
6.0
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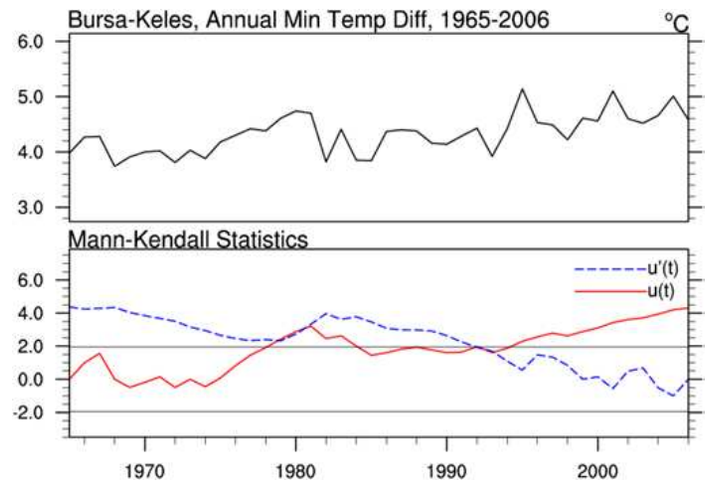
1970
1980
1990
2000

(a)


Bursa-Keles, Annual Min Temp Diff, 1965-2006
°C
6.0
5.0
4.0
3.0
Mann-Kendall Statistics
u'(t)
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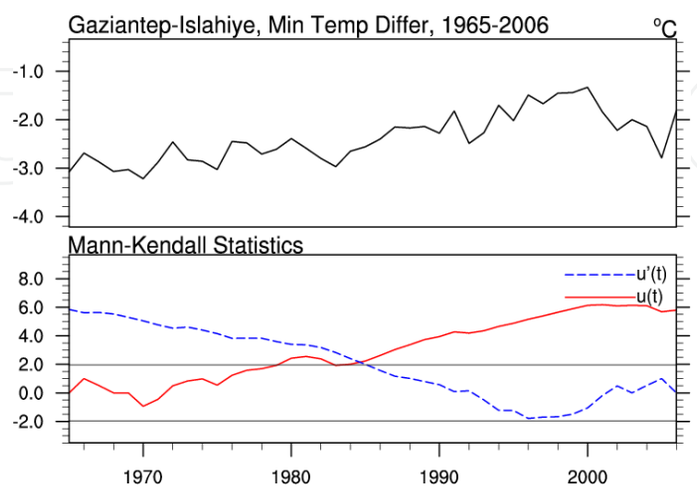
1970
1980
1990
2000

(b)


Gaziantep-Islahiye, Min Temp Differ, 1965-2006
°C
-1.0
-2.0
-3.0
-4.0
Mann-Kendall Statistics
u'(t)
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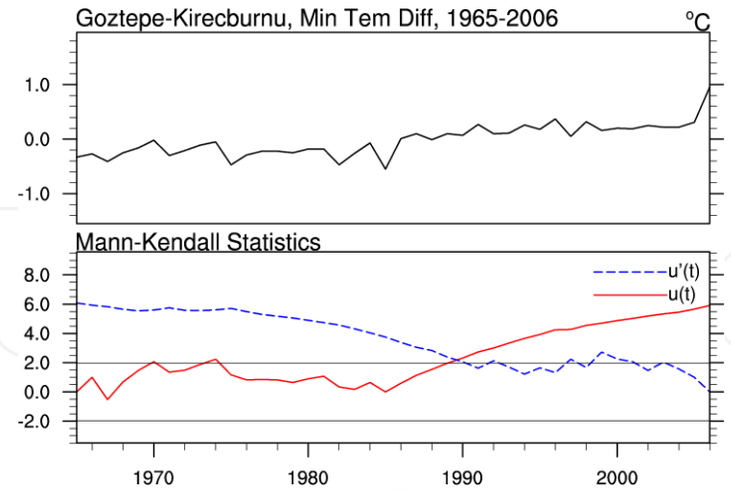

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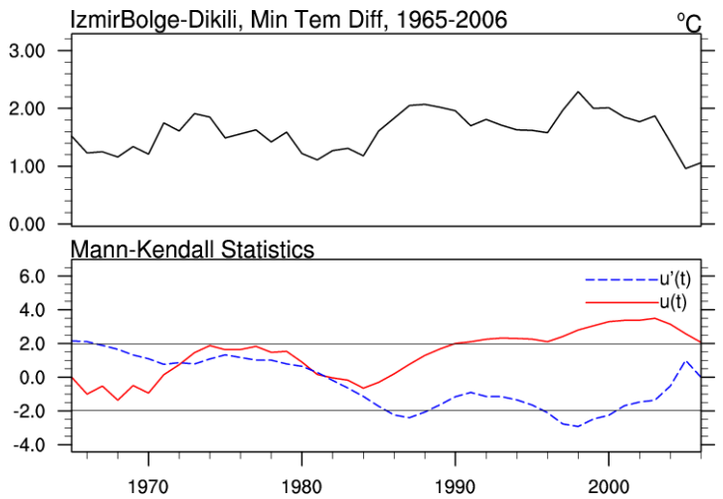
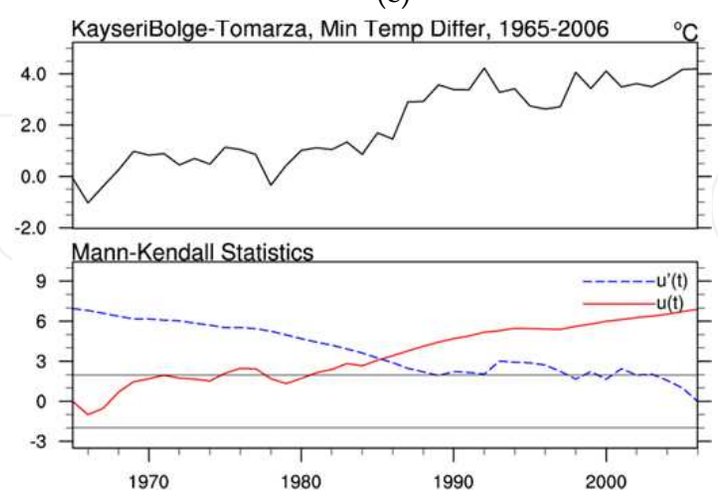


(e)



(f)

Figure 6. The annual time series and Mann-Kendall tests for the minimum temperature differences between; a) Ankara Bolge – Beypazari, b) Bursa – Keles, c) Gaziantep – Islahiye, d) Istanbul (Goztepe) – Kirecburnu, e) Izmir Bolge – Dikili, f) Kayseri Bolge – Tomarza

the UHI for Istanbul, two urban stations are selected on the both sides for representing the all city. The urban stations used in the European and the Asian sides are Florya and Goztepe, respectively. The annual minimum temperature statistics of the urban stations of the city show significantly increasing trend (Table 3). The urban-rural pairs show significantly increasing UHI effect (>2.5) in the city (Fig. 6d and Table 4), which is an accepting result for a highly urbanized city of Istanbul.

Izmir is the third largest city in Turkey with respect to population and comprising significant amount of economic activity in its region. The city is located in the west coast of Anatolia (Aegean Region) and has a typical Mediterranean climate. The city has encountered important amount of urban growth and with the 2007 above the 70% of the city live in the urban parts of the city (Fig. 2). Urban station, Izmir Bolge has a significant increasing trend in annual minimum temperature statistics (Table 3a). The Izmir Bolge-Dikili difference has a significant increasing trend above 95% (Fig. 6e). Kayseri is the other city studied in the same region of Anatolia along with Ankara. Kayseri is another big and also industrialized city in the region. Three rural stations are selected for the Kayseri with a one urban station. All the urban-rural pairs show a positive trend above the 95% with Mann Kendall values over 5.0 (Table 4), pointing out the UHI effect strongly in Kayseri (Fig. 6f).

Station pairs (urban-rural)	T_{min} Statistics (1965-2006)
Ankara Bolge – Polatli	5.88
Ankara Bolge - Kizilcahamam	2.92
Ankara Bolge – Beypazari	6.25
Ankara Bolge - Esenboga	4.30
Ankara Bolge - Nallihan	5.13
Bursa - Keles	4,30
Gaziantep - Islahiye	5.82
Istanbul (Florya) - Kirecburnu	2.66
Istanbul (Florya) - Kumkoy	3.74
Istanbul (Florya) - Sile	4.63
Istanbul (Goztepe) - Kirecburnu	6.01
Istanbul (Goztepe) - Kumkoy	4.63
Istanbul (Goztepe) - Sile	5.75
Izmir Bolge - Dikili	2.13
Kayseri Bolge - Develi	5.06
Kayseri Bolge - Pinarbasi	5.86
Kayseri Bolge - Tomarza	6.93
Mersin - Erdemli Alata	6.82
Sanliurfa Bolge - Birecik	5.54

Table 4. Mann Kendall statistics of the urban and rural minimum temperature differences

In 1965, practically there was no difference in daily minimum temperatures between urban and rural stations. However, as of 1985, urban station is approximately 2 °C warmer than

the rural station. This trend accelerated and as of 2006, the urban station is over 4 °C warmer than rural. Mann-Kendall plot verifies this finding; since by 1985 the trend is estimated to be significant. Results for other urban-rural pairs are given in Table 4. All of the 19 pairs show a statistically significant increase in urban temperatures as compared to rural values.

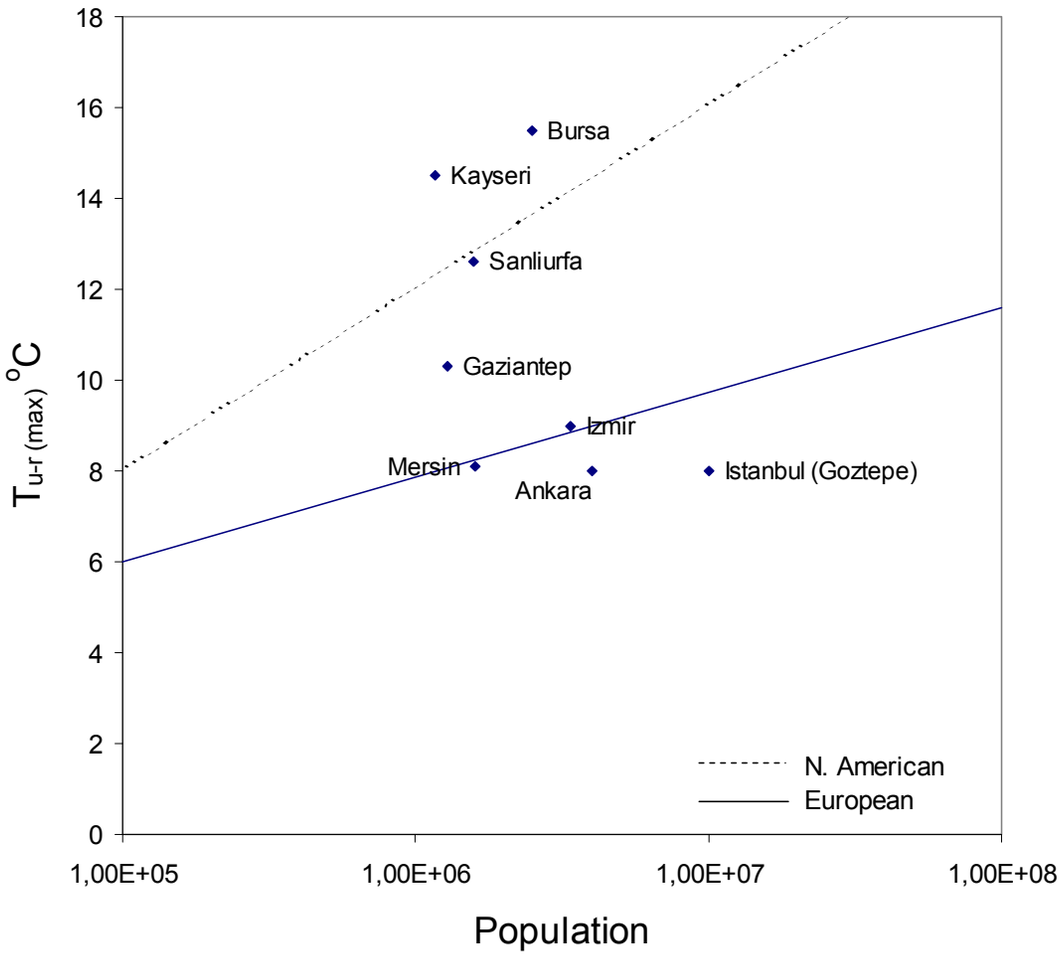


Figure 7. The intensity of maximum UHI of the selected cities with respect to the logarithm of 2007 populations

Fig. 7 presents the intensity of maximum UHI in relation with the logarithm of the population. Magnitude of maximum UHI effect is calculated by subtracting the minimum rural temperature from the minimum urban temperature and the maximum difference between them is taken as the maximum UHI intensity (Tayanc & Toros, 1997). The linear curves of Oke (1973) for the maximum UHI intensity of European and North American cities are illustrated in the figure. Maximum UHI intensities of the stations are almost positively correlated with Oke's fit for European cities; Istanbul (Goztepe - Sile), Izmir (Izmir – Dikili), Ankara (Ankara - Beypazari), Mersin (Mersin - Erdemli Alata), and Gaziantep (Gaziantep - Islahiye). But the cities; Kayseri, Sanliurfa, and Bursa are correlated with the North America line. This difference may be about the lower population densities or different sizes of settlements, which may generate higher $\Delta T_{u\text{-}r}$ values.

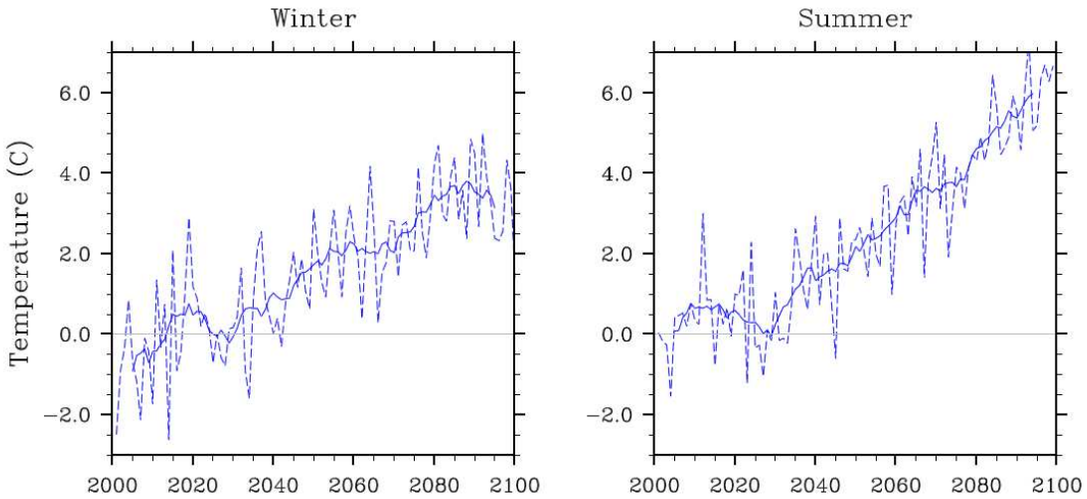


Figure 8. Mean temperature anomaly of the Anatolian Peninsula; winter, and summer season

4. Conclusion

Urbanization makes significant changes in the surface of the earth, and this change makes variations in the trends of the temperatures. In this study, urbanization effects on the temperature trends are investigated at the selected stations in the Anatolian Peninsula, which is located at the confluence of Europe, Asia, and Africa. Interactions between the climates of these continents, which have different characteristics, affect the Mediterranean region including the Anatolian Peninsula causing temporal and spatial variations (Giorgi & Lionello, 2008). Complex terrain of the study area, presence of water bodies as well as urbanization effects on local climate further complicates the system. In this study, we aim to quantify the UHI effect by contrasting the temperatures between urban-rural areas. Study area includes 81 cities of which 79 of them have population over 100,000. We have chosen 9 urban and 16 rural meteorological stations (in the close proximity of the city) in 8 cities.

The findings of this study suggest that there is no statistically significant increase in rural daily minimum temperatures between 1965-2006. However, all the urban sites show significant increase, which is a strong indication for the existence of UHI effect over this region. These findings are different from the previous studies (Karaca et al., 1995; Tayanc & Toros, 1997), which suggest either no significant or is a cooling trend existing for this region. This is mainly due to the fact that our study includes the period between 1960 and 2006, where a clear upward trend is seen especially after 1990s. Similar to our findings, Kataoka et al. (2009) demonstrated the UHI in several Asian cities.

IPCC has identified Eastern Mediterranean covering Anatolian Peninsula as one of the most vulnerable zones in terms of Climate Change (Stern Review, 2006). Our group conducted research studies (Scientific and Technical Research Council of Turkey-TUBITAK Project No: 105G015) to investigate climate change over Anatolia via regional climate models. Fig. 8 presents anomaly of temperature for Anatolian Peninsula, which were estimated by regional model in a 27 km resolution for the period 2000-2100 as compared to reference period 1961-1990, following the International Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) A2 forcing. In winter, temperatures do not show increasing trend until

2030. However, there is almost linear increase reaching up to 3°C at the end of the century. In summer the trend is much more significant and reaches up to 5 °C (Fig. 8b). It should be pointed out that most of the climate models do not take UHI effect into account, since climate models use fixed Land Use/Land Classification (LU/LC) for the simulation period. Therefore, there is a possibility of greater increase in temperatures over urban areas, when UHI effect is considered. Such analysis is definitely required to better understand future climate.

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Acknowledgement

This study is partly supported by a grant (108Y064) from TUBITAK (The Scientific and Technological Research Council of Turkey).

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