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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

ARE SUMMER RESORTS COOLER IN SUMMER? A CASE STUDY OF İZMİR PROVINCE

Sayfiye Alanları Yazları Daha Serin mi? İzmir İli Örneği

Doğukan Doğu YAVAŞLI[1]

Kırşehir Ahi Evran Üniversitesi Fen-Edebiyat Fakültesi Coğrafya Bölümü, Kırşehir
dogukan.yavasli@ahievran.edu.tr

M. Kirami ÖLGEN

Ege Üniversitesi Edebiyat Fakültesi Coğrafya Bölümü, İzmir
kirami.olgen@ege.edu.tr

Volkan ZOĞAL

Ege Üniversitesi Edebiyat Fakültesi Coğrafya Bölümü, İzmir
volkan.zogal@ege.edu.tr

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Abstract

Satellite based land surface temperatures (LST) are widely used for urban climate studies particularly at the areas where spatial distribution of meteorological data is not adequate. This paper evaluates Moderate Resolution Imaging Spectroradiometer (MODIS) data to detect summer daytime and nighttime LSTs at İzmir city center and major summer resort areas around it. We investigated whether these summer resorts are cooler in summer than the İzmir city center for both daytime and nighttime temperatures for the 2003-2016 period. We have found that Çandarlı and Dikili have higher LSTs during daytime than İzmir city center for the most of the period while İzmir city center has higher LSTs than all the other summer resorts at nighttime. Mann – Kendall trend analysis shows that there is statistically significant negative trend at the 1% significance level for Dikili and Eski Foça and 5% significance level for İzmir for daytime LSTs. However, statistically significant positive trend is observed for nighttime LST's at the 1% significance level for Çeşme, Dikili and Urla while Çandarlı, Eski Foça and Yeni Foça has a positive trend at the 5% significance level. We attribute to nighttime positive trends of LSTs to urban heat island effect regarding urbanization and the increase of artificial surfaces in those areas.

Keywords: Land surface temperature, urban heat island, Mann – Kendall trend analysis, MODIS.

[1] Sorumlu Yazar/ Corresponding author: Doğukan Doğu YAVAŞLI / dogukan.yavasli@ahievran.edu.tr

Öz

Uydu tabanlı yeryüzü sıcaklıkları iklim çalışmalarında, özellikle de meteoroloji istasyonlarının mekânsal dağılımının yeterli olmadığı alanlarda sıklıkla kullanılmaktadır. Bu çalışma İzmir kent merkezi ve çevresindeki belli başlı sayfiye alanlardaki yaz mevsimine ait gündüz ve gece yeryüzü sıcaklıklarını belirlemede Moderate Resolution Imaging Spectroradiometer (MODIS) verisini kullanmaktadır. Çalışma kapsamında 2003 – 2016 yılları arasında hem gündüz hem de gece sıcaklıklarına göre sayfiye alanlarının İzmir kent merkezine göre daha serin olup olmadığı incelenmiştir. Bulgulara göre söz konusu dönemin büyük çoğunluğunda İzmir kent merkezine göre Çandarlı ve Dikili gündüzleri daha yüksek yüzey sıcaklıklarına sahipken; gece sıcaklıklarında İzmir kent merkezi incelenen sayfiye istasyonların tamamından daha yüksek yüzey sıcaklığına sahiptir. Mann – Kendall eğilim analizine göre gündüz yüzey sıcaklıklarında Dikili ve Eski Foça'da %1 düzeyinde, İzmir kent merkezinde %5 düzeyinde istatistiksel olarak anlamlı bir azalış eğilimi görülmektedir. Buna karşın, gece yüzey sıcaklıklarında Çeşme, Dikili ve Urla'da %1 düzeyinde, Çandarlı, Eski Foça ve Yeni Foça'da ise %5 düzeyinde istatistiksel olarak anlamlı bir artış eğilimi tespit edilmiştir. Gece yüzey sıcaklıklarındaki söz konusu pozitif eğilimin bu alanlarda kentleşmenin ve dolayısıyla yapay yüzeylerin artışı ile ilişkili olduğu düşünülmektedir.

Anahtar Kelimeler: Yeryüzü sıcaklığı, kentsel ısı adası, Mann – Kendall eğilim analizi, MODIS.

1. Introduction

The land surface temperature (LST) is the radiative temperature of the land surface or to put it all in simple terms it is the measurement of how hot the land is. It differs from air temperature, which is typically measured at 2 m above ground. Even though air temperatures and LSTs are strongly correlated (Vogt et al., 1997; Vancutsem et al., 2010; Benali et al., 2012) both have different physical meanings because land heats and cools more quickly than air. It is known that during daytime, surface temperature is generally higher than air temperature, and at nighttime, the opposite occurs (Cresswell et al., 1999; Çiçek et al., 2013). Surface temperature affects the thermal comfort thus the health of people (Rasul et al., 2016).

Since the LST changes rapidly in space as well as in time, the detection of its spatial and temporal distribution requires detailed measurements (Li et al., 2013; Sekertekin vd., 2016). Satellite-based thermal infrared data is linked to the LST through the radiative transfer equation and LST can be obtained from satellites using various algorithms and methods that take emissivity and atmospheric corrections into account.

Satellite based LSTs are widely used for urban climate studies (Voogt and Oke, 2003; Kaya et al., 2012) since the change in urban/non-urban land uses can result in warming or cooling trends. These changes usually cause a phenomenon called the urban heat island (UHI) referring to the positive difference in air and surface temperature between an urban area and its non-urban surroundings and studies of UHIs have often cited urban area expansion as a main factor in the UHI development (Oke, 1973). Replacement of impervious surfaces and human-made structures with vegetation result with temperature increase in those areas. The UHI implicitly distress on human thermal comfort, which is the result of the combined effect of temperature, wind speed, air humidity and radiation (Höppe, 1999).

The distress on human thermal comfort in the cities causes people to travel non-urban areas such as the second homes in summer resort areas or highlands especially on the warm period of the year. This study focuses on LSTs of İzmir city center and the summer resorts around it using MODIS satellite data and tries to answer the question if these summer resorts fulfill the need of cooling on summers for inhabitants of İzmir. For this purpose, we compare the LSTs of the İzmir city center and summer resorts around along with the investigation of the change in the LSTs for 2003 – 2016 period using non-parametric Mann-Kendall (M-K) test. One of the novel contributions of this paper is determination of summer LSTs at the summer resort settlements of İzmir in spatially

comprehensive way where there are either no meteorological station or they are not dating back further for climatological analysis. Another contribution is the detection of the temporal change for LSTs for 14-year period and the significance of the trend.

2. Study Area

The study area, İzmir province is located at the west coast of Turkey (fig. 1). This study focuses on İzmir city center and major summer resorts Dikili, Çandarlı, Yeni Foça, Eski Foça, Urla, Çeşme and Gümüldür around it. Typical Mediterranean climate that is observed at İzmir province characterized by mild, rainy winters and hot, dry summers and there are strong inter-annual variability of climate components (Erlat, 2003; Bolle, 2012). The average air temperatures for summer months are between 25°C – 28°C however, daily maximums with more than 40°C can occur.

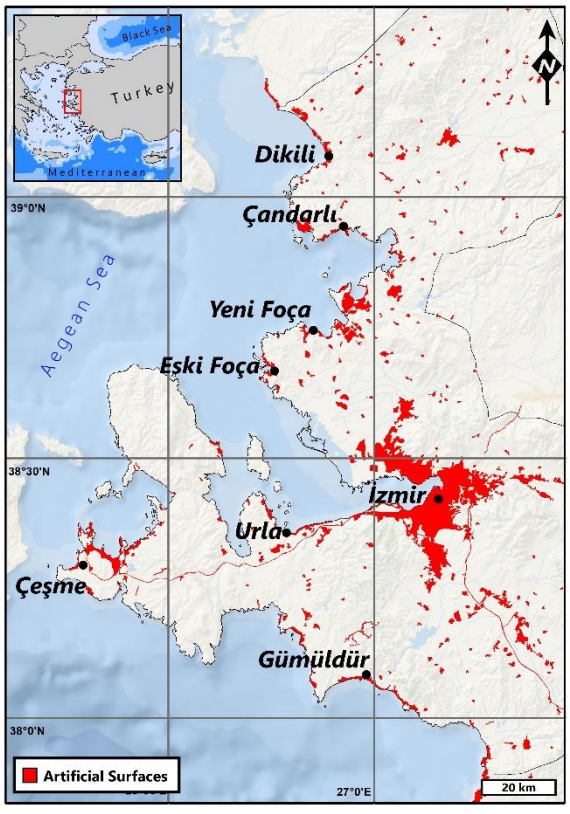

Figure 1- Izmir and selected summer resort areas. (Background layer credits: Esri, DeLorme, GEBCO, NOAA NGDC)

The summer resorts at İzmir are coastal settlements used especially in summers by both people from and out İzmir. People usually travel to these resorts (daytrip or long duration) especially in summers for swimming activities and getting away from excessive hot weather and city life distress.

While the primary economic activity before 1980s' at these areas were fishing and/or agriculture, from this date forward, the high demand on touristic facilities and vacation houses converted their rural pattern to urban by the rapid increase on second homes and their population (Özgüç, 2017). Although there are no official statistics for İzmir, The Ministry of Tourism have announced that, the total number of second homes in Turkey were 102.400 in 1990 (Turizm Bakanlığı, 1990) and 559.934 in 2013 according to General Directorate of Civil Registration and Citizenship (NVİ, 2013).

3. Data

Although there are two main meteorological stations in İzmir city center having data back to 1930s' at the summer resort areas, either there are no meteorological stations (i.e. Çandarlı) or they are not dating back further for climatological analysis. Therefore, we preferred using Moderate Resolution Imaging Spectroradiometer (MODIS) LST and Emissivity 8-Day composite products (MYD11A2) acquired from EarthExplorer website (https://earthexplorer.usgs.gov/) for the period from 2003 to 2016. The data were filtered based on the QA flags provided in the quality control layers of the products. Aqua satellite passes over the study area at approximately 01:00 and 14:00 local time letting us to have daytime and nighttime LST values for the study area.

We used CORINE Land Cover (CLC) 2000 and 2012 to determine the boundary of the urban area of Izmir and other summer resort areas instead of administrative divisions.

4. Methodology

The CLC 2012 has been used to determine the existing artificial surfaces corresponding İzmir urban area and the summer resort areas. According to the CLC data sets the artificial surfaces class

contains urban fabric, industrial, commercial and transport units, mine dump and construction sites and non-agricultural vegetated areas. To avoid a mixture of artificial surface pixels and others, 1 km buffer zone has been applied.

The MODIS MYD11A2 products of each year's summer season (June-July-August) has been used to assess the LSTs. The MODIS LST data of 14-year period is converted to Celsius degrees. Mean pixel values have been calculated for each summer period for daytime and nighttime LSTs. All the pixels representing İzmir city center and the summer resort areas then averaged giving the average LST for each summer ($Pixel_{Mean}$) (fig. 2).

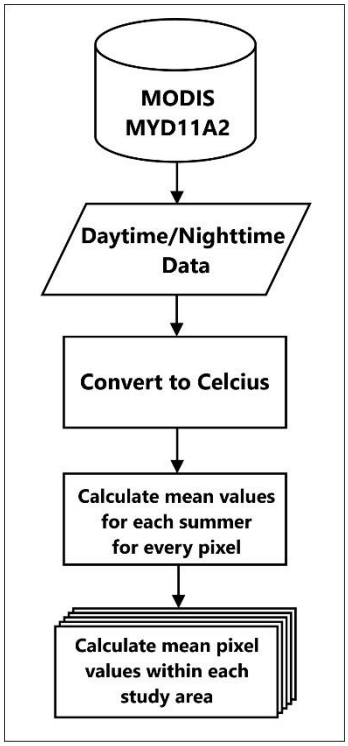

Figure 2- Flowchart of the calculation of $Pixel_{Mean}$ values from MODIS data

The trends of LSTs has been examined using the non-parametric M-K test. The M-K test is a nonparametric test for monotonic trends that provides an indication of whether a trend exists and whether the trend is positive or negative. Two hypotheses were tested using the M-K: the null hypothesis, H_0, that there is no trend in the time series; and the alternative hypothesis, H_a, that there is a statistically significant trend in the series, for a given α significance level. In this study, significance levels 5% and 1% were used. We have used both the Kendall tau coefficient (τ) and M-K coefficient (S) to identify rank correlation. Kendall τ is defined as the actual rating score of correlation divided by the maximum probable score and is calculated as:

$$\boldsymbol{\tau = \frac{S}{0,5n(n-1)}}$$

(eq.1)

where n denotes the sample size. The M-K coefficient is calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

(eq. 2)

where n is the number of observation values in the series, x_1, x_2, … x_n represent n data points where x_j represents the data point at time j. $Sign(x_j - x_k)$ is the sign function as:

$$sign\left(x_j - x_k\right) = \begin{cases} 1 & x_j > x_k \\ 0 & x_j = x_k \\ -1 & x_k < x_k \end{cases}$$

(eq. 3)

A high positive value of τ or S indicates an increasing trend where a low negative value is an indicator of a decreasing trend. However, it is necessary to compute the probability associated with τ or S to statistically quantify the significance of the trend. τ ranges from -1 to +1 and closer number to these, means a stronger relationship. Sen's slope estimator (Sen, 1968) is used to estimate the slope (change per unit time) of the trend. The averages of all the pixels associated with İzmir city center and summer resort areas for each summer is used for M-K trend analysis.

5. Results and Discussion

The annual averages of summer LSTs show that İzmir city center is warmer in daytime comparing with summer resort areas except for Çandarlı and Dikili (fig. 3). For the nighttime

LSTs, İzmir city center is warmer than all summer resort areas (fig. 4). The upward trend can be noticed for the nighttime LSTs in all areas. It should be noted that the effect of 2007 South Europe heat wave (Founda and Giannakopoulos, 2009) can be observed in both daytime and nighttime LSTs while 2010 summer heat wave (Barriopedro et al., 2011) can only be distinguished at the nighttime LSTs.

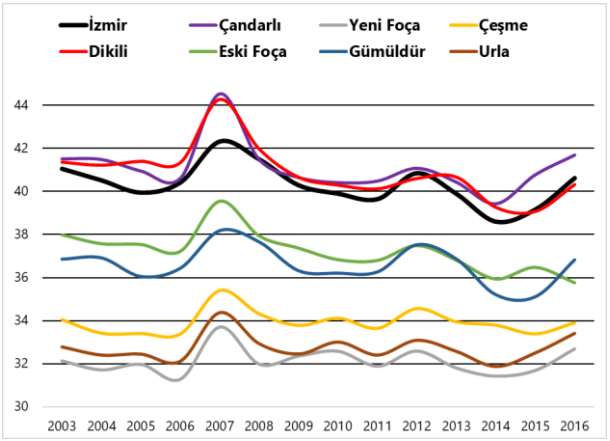

Figure 3: Temporal change in daytime $Pixel_{Mean}$ values for İzmir city center and the summer resort areas

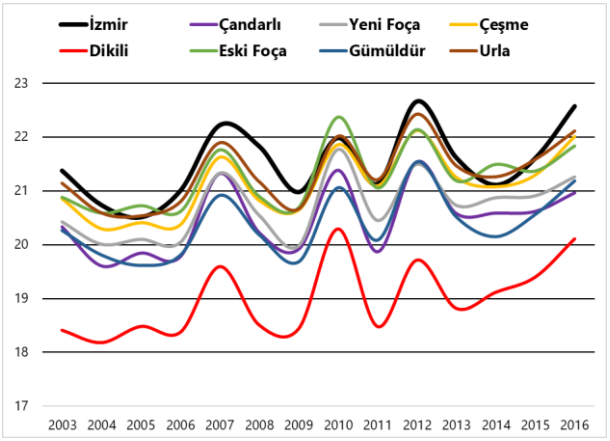

Figure 4-Temporal change in nighttime $Pixel_{Mean}$ values for İzmir city center and the summer resort areas

The M-K test shows that there is statistically significant negative trend at the 1% significance level for Dikili and Eski Foça and 5% significance level for İzmir for daytime LSTs (table 1 and fig. 5). The Sen's slope values indicate that the negative trend is more than 1°C per decade for these areas. Negative trend with no significance can be observed at Çandarlı, Çeşme and Gümüldür while Urla and Yeni Foça have positive trend with no significance.

Table 1- Results of the Mann-Kendall test for LSTs. (* Statistically significant trend at the 5% significance level. ** Statistically significant trend at the 1% significance level.).

	Day		**Night**	
	M-K τ	Sen's Slope	M-K τ	Sen's Slope
İzmir	-0.41*	-0.12	0.32	0.09
Çandarlı	-0.30	-0.06	0.49*	0.09
Çeşme	-0.01	0.00	0.52**	0.08
Dikili	-0.54**	-0.16	0.52**	0.09
Eski Foça	-0.69**	-0.15	0.47*	0.08
Gümüldür	-0.25	-0.09	0.36	0.07
Urla	0.12	0.01	0.52**	0.09
Yeni Foça	0.01	0.00	0.41*	0.08

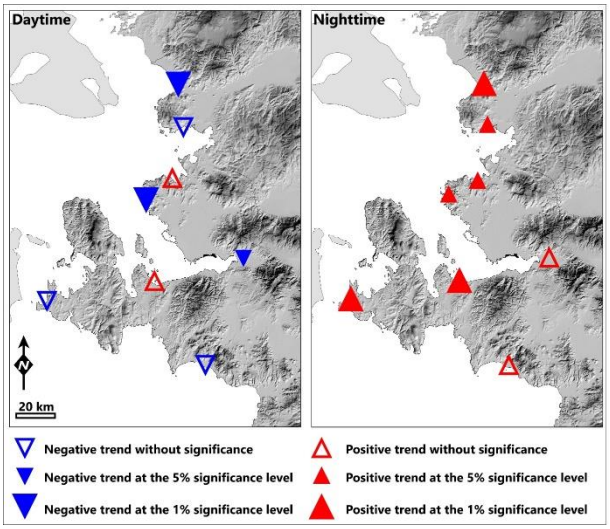

Figure 5- Distribution of Mann-Kendal trend analysis results at the study area for daytime and nighttime LSTs. See fig. ? for the labels of the locations.

On the other hand, statistically significant positive trend can be noticed at the 1% significance level for Çeşme, Dikili and Urla while Çandarlı, Eski Foça and Yeni Foça has a positive trend at the 5% significance level (table 1 and fig. 5). The other areas, İzmir city center and Gümüldür, have also a positive trend without significance. The

Sen's slope values indicate that the positive trend is between 0.7°C - 0.9°C per decade for nighttime LSTs for all the areas.

According to the results, İzmir city center, Çandarlı and Dikili are warmer than all the other areas at daytime and there is no substantial difference in the daytime LSTs for these three areas. In terms of nighttime LSTs, İzmir city center is warmer than all the summer resort areas for almost all 14-year period. Apart from humidity and wind speed, it can be affirmed that people have a better thermal comfort at the summer resorts, especially in nighttime LSTs for all the inspected period. On the other hand, the results of the M-K analysis shows that this situation is changing. Six of the seven investigated summer resort areas have statistically significant positive trend for the nighttime LSTs. The larger magnitude of the summer nighttime warming rates are consistent with Türkeş et al. (2002) and it is associated with the rapid urbanization. This is generally explained by the higher heat capacity of urban structures and impervious surfaces that store more energy during daytime and slowly releases it during nighttime (Yang et al., 2011). Considering our results, it can be concluded that the nights in those summer resorts are getting warmer and this can be related to the urbanization. The urbanization and the expansion of the settlement areas are examined using CORINE land cover data. The change of the artificial surfaces that are associated with urbanization between 2000 and 2012 shows that the artificial surface areas have been increased at all the areas and proportionally more at the summer resorts (fig. 6).

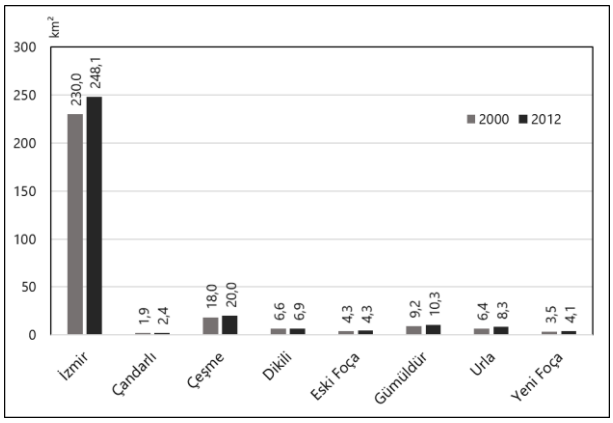

Figure 6- The change of 2000 and 2012 artificial surface areas for İzmir and other summer resort areas according to CORINE Land Cover data.

6. Conclusions

The study presented here focuses on the summer LSTs of İzmir city center and surrounding major summer resort areas and the change of summer LSTs in 14-year period. Our hypothesis is that the summer resort areas are expanding and becoming "urban" and the urban heat island effect in these areas are increasing making these areas hotter.

The results show that İzmir city center is warmer than all summer resort areas for daytime and nighttime LSTs. According to the M-K trend analysis daytime summer LSTs have a decrease for 14-year period except for Yeni Foça and Urla. On the other hand, nighttime summer LSTs are increasing at the summer resort areas.

We acknowledge that air temperature can also express the thermal comfort; however, it has limited ability to describe spatial distribution over large areas most particularly at the areas where the number of meteorological stations is limited. The thermal comfort is also a function of air and surface temperature, humidity and wind however; we have externalized latter two due to the lack of spatial distribution of meteorological stations. Humidity, topography wind data can be taken into consideration for further research.

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