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EXTREME MAXIMUM AND MINIMUM AIR TEMPERATURE IN MEDİTERRANEAN COASTS IN TURKEY

ABSTRACT. In this study, we determined extreme maximum and minimum temperatures in both summer and winter seasons at the stations in the Mediterranean coastal areas of Turkey. In the study, the data of 24 meteorological stations for the daily maximum and minimum temperatures of the period from 1970–2010 were used. From this database, a set of four extreme temperature indices applied warm (TX90) and cold (TN10) days and warm spells (WSDI) and cold spell duration (CSDI). The threshold values were calculated for each station to determine the temperatures that were above and below the seasonal norms in winter and summer. The TX90 index displays a positive statistically significant trend, while TN10 display negative non-significant trend. The occurrence of warm spells shows statistically significant increasing trend while the cold spells shows significantly decreasing trend over the Mediterranean coastline in Turkey.

KEY WORDS: Extremes, Mediterranean, climate change, maximum and minimum temperatures.

INTRODUCTION

Extremes are defined with the maximum and minimum measurements of atmospheric variables that can be expected to occur at a certain place and time [Rohli and Vega, 2012] that established a long period of observations.

As well as this, the classification of extreme events, extreme impacts and disasters is affected by the measured physical attributes of weather or climatic variables or the vulnerability of social systems.

Robust of record-breaking heatwaves and coldwaves occur each year somewhere on the earth. Extreme events have been experienced in many part of Mediterranean basin during the past decade. The life and socioeconomic effected of extremes temperature have examined by the researchers [e.g. Watson et al. 1997; Parry, 2000].

Today, when we talk about extreme temperature, comes to mind high degrees or heatwaves. Because perception of communities on climate change or variability, strongly affected by seasonal extremes. Today, especially after 1970s, we experienced extremely hot conditions. But for example, 1960s and 1970s is known two cold decades [Kukla et al, 1977]. This variability is effect to the community perception today and past. But in reality, we know that our era is interglacial period as named "Holocene" and about 11k years, temperature is rising in big scale.

Especially, 2003 and 2007 summers experienced warm years in European countries, Balkan Peninsula and Turkey [Schär et al., 2003; Beniston & Diaz 2004; Busuioc et al., 2007; Ünal et al., 2012; Acar Deniz, 2013; Acar Deniz and Gönençgil, 2015]. As an example Metoffice [www.metoffice.gov.uk]: *The "heatwave" of 2003; More than 20,000 people* *died after a record-breaking heatwave left Europe sweltering in August 2003. The period of extreme heat is thought to be the warmest for up to 500 years, and many European countries experienced their highest temperatures on record. World Meteorological Organization (WMO) and cited by the MetOffice is "when the daily maximum temperature in more than five consecutive days exceeds the average maximum temperature by 5 °C(9°F), the normal period being 1961–1990".*

In simpler terms, a heat wave is a prolonged (long-term) period of excessively hot weather, which may be accompanied by high humidity. Luterbacher et al. [2004] indicate that the summer of 2003, should be the hottest year in at last 500 years.

Severity and spatial scale of the heatwaves are an important effect on environmental, social, economic and health. In particular, because the Mediterranean basin is sensitive to climate change, the human activities in this area have a greater effect. Beniston et al. [2007] suggest that regional surface warming causes the frequency, intensity and duration of heat waves that increases over European continent. Also, the authors postulate that by the end of the twenty first century, especially central Europe countries will suffer the same number of hot days as are currently experienced in southern Europe. The intensity of extreme temperatures increases in southern Europe more rapidly than in central Europe.

Current studies also aim to explain the temperature anomalies in the Mediterranean region [Unkasevic and Tosic, 2013; Unkasevic and Tosic, 2009; Beniston et al., 2007; Baldi et al, 2006; Kostopoulou and Jones, 2005]. Hertig et al. [2010] suggests that mostly insignificant trends for the 5th percentile of minimum temperatures in winter during the period 1961–1990. They have analyzed significant increases of the 5th percentile of minimum temperatures occurred mainly at stations in the central-northern Mediterranean area with values of more than 2 °C in some cases (e.g. Palermo, Italy or Istanbul, Turkey).

In summer 2010, many cities in eastern Europe recorded extremely high values of daytime (for example, Moscow reached 38.2 °C), nighttime (Kiev reached 25 °C), and daily mean (Helsinki reached 26.1 °C) temperatures and during the same period, parts of eastern Asia also experienced extremely warm temperatures, and Pakistan was hit by devastating monsoon floods [Barripedro et al., 2011].

In addition, the 95th percentile of maximum temperature trend is recorded with mostly in the western Mediterranean area and such trend conversely decreases in the eastern Mediterranean region [Acar Deniz and Gönençgil, 2015]. Moreover, projections show that heatwaves will become more intense, frequent and longer-lasting.

Finally, extreme hot and cold events could be important the understanding of Mediterranean climate variability because this region of climate vulnerability to global climate change.

Also, Tourism are agriculture main economic activity in this area and chancing climate should effect directly these economic activity. Because of that, we chose this study area and examine the chancing extreme climate conditions. The aim of this study is to analyze the maximum and minimum temperature indices during the hottest months of the year (June-July-August) and coldest months of the year (December, January and February). In this study, we examine the experience of winter and summer extreme hot and cold days and also warm and cold spell durations in the Mediterranean seacoast line of Turkey. The objective of this study is to define Turkey's winter and summer extreme temperature variability and trend patterns over 1965–2014 periods.

DATA AND METHOD

The study area is spread southern part of Anatolian Peninsula, Turkey. The temperature records are collected based on daily maximum and minimum temperatures data provided by Turkish State Meteorological Service [http://

www.mgm.gov.tr], winter and summer seasons. Namely, these are air temperature data recorded from 24 stations in Turkey during the period of 1965–2014 (Table 1). Locations of these selected stations are shown in Fig. 1.

Table 1. List of stations with their latitudes, longitudes and altitudes

Station name	Latitude	Longitude	Altitude (m)
Dalaman	36,77	28,79	12
Fethiye	36,62	29,12	3
Antalya	36,90	30,79	64
Alanya	36,55	31,98	6
Anamur	36,06	32,86	2
Silifke	36,38	33,93	10
Mersin	36,78	34,60	7
Adana	37,00	35,34	23
Iskenderun	36,59	36,15	4
Antakya	36,20	36,15	104
Finike	36,30	30,14	2
Kaş	36,20	29,65	153
Köyceğiz	36,97	28,68	24
Manavgat	36,78	31,44	38
Mut	36,65	33,43	340
Erdemli	36,62	34,33	7
Ceyhan	37,01	35,79	30
Dörtyol	36,82	36,19	29
Islahiye	36,08	35,94	4
Kale	36,24	29,97	25
Gazipaşa	36,27	32,30	21
Yumurtalık	36,76	35,79	34
Karataş	36,56	35,38	22
Samandağ	36,08	35,94	4

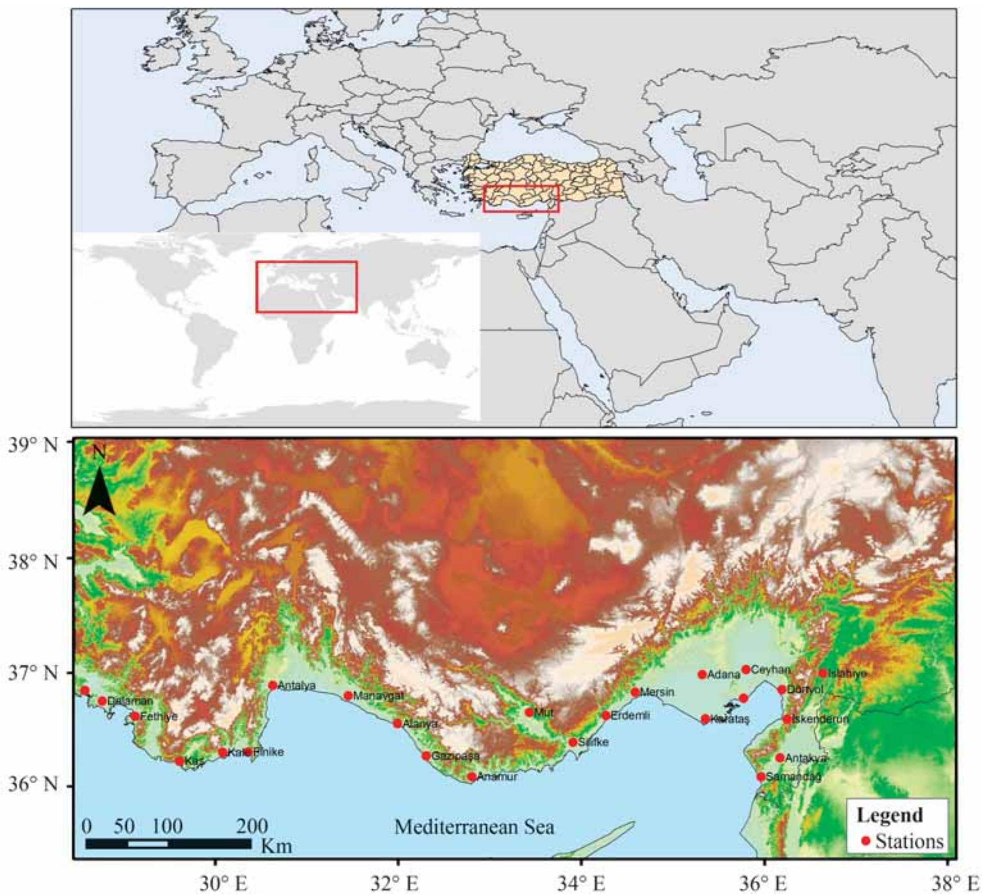


Fig. 1. The geographical distribution of meteorological stations.

In the recent years, various indices have been used in extreme event studies. Used climate change indices for temperature recommended by WMO–CCL/CLIVAR list of over 50 climate change indices [Alexander et al., 2006; Frich et al., 2002; Klein Tank and Können, 2003]. The list internationally concur trends in indices of climate extremes are calculated on the basis of daily minimum and maximum temperature series.

We selected 4 indices of climate extremes to be extracted from daily maximum and minimum temperature. These climate indices (hot and cold days, warm and cold spell duration) are defined as days with maximum temperature (TX) and minimum temperature (TN) anomalies above and below a certain percentile of TX (90) and TN (10) anomalies and warm and cold spell durations. The temperature indices were selected for this study and their description are shown in Table 2.

The temperatures indices based on station-related thresholds that hot (cold) day is defined as a day when the daily maximum (minimum temperature) exceeds (fall behind) 90^{th} (10^{th}) percentiles. The temperature indices describe warm and cold extremes in summer and winter seasons. As well as this, a linear trend in the warm days and cold night is determined with Mann-Kendall rank correlation test. According to Mann-Kendall test τ is a value that indicates magnitude of the observations. N is the number of observations in the sample and n is the number of data points. The P statistic is calculated by;

$$P = \sum_{i=1}^{N-1} n_i .$$

Mann Kendall test statistic τ is calculated as follows;

$$\tau = \frac{4P}{N(N-1)} - 1.$$

The value of the test statistics is normal for all N values larger than 10. The significance test is calculated as follows;

$$\tau_{(t)} = 0 \pm t_g \frac{(4N+10)}{9N(N-1)},$$

where t_g value is the requested probability point in the normal distribution (two sided). A positive value of τ indicates an upward trend; a negative value of τ indicates a downward trend [Mann, 1945; Kendall, 1975].

The values of $u(t)$ and $u'(t)$ are used to determine the trend in the time series. Similarly to the calculation of progressive rows of statistics $u(t)$, the retrograde rows of statistics $u'(t)$ are computed backwards starting from the end of series. $u(t)$ is significant at a desired level of significance, one can decide whether it is an increasing or decreasing trend depending on whether $u(t) > 0$ or $u(t) < 0$.

This study focuses on observed trends in warm days and warm spell duration and cold night and cold spell duration indices in summer and winter seasons during 1965–2014 in Mediterranean coastline of Turkey.

Cold spell duration index (CSDI), annual count of days with at least 6 consecutive days when $TN < 10^{th}$ percentile. Let TN_{ij} be the daily minimum temperature on day i in period j and let TN_{in} 10 be the calendar day 10^{th} percentile

Table 2. Definitions of the minimum and maximum air temperature indices used in this study

ID	İndicator name	Definations	Units
TX90p	Warm days	Percentage of time when daily max temperature > 90^{th} percentile	Days
TN10p	Cool nights	Percentage of time when daily max temperature < 10^{th} percentile	Days
WSDI	Warm spell duration index	Count of days w at least 6 cons. days w tmax > 90th percentile	Days
CSDI	Cold spell duration index	Count of days w at least 6 cons. days w tmin < 10th percentile	Days

centered on a 5-day window for the base period 1961–1990. Then the number of days per period is summed where, in intervals of at least 6 consecutive days:

$TN_{ij} < TN_{in}10$.

Warm spell duration index (WSDI), annual count of days with at least 6 consecutive days when $TX > 90^{th}$ percentile. Let TX_{ij} be the daily maximum temperature on day i in period j and let TX_{in} 90 be the calendar day 90^{th} percentile centered on a 5-day window for the base period 1961–1990. Then the number of days per period is summed where, in intervals of at least 6 consecutive days:

$TX_{ij} > TX_{in}90$.

RESULTS

Turkey is one of the rapidly urbanizing countries in the developing countries of the world. According to the results of the 2007 census the population of Turkey increased from 70.586.256 in 2007 to 77.695.904 in 2014 [TUIK, ABPRS 2007–2014]. Antalya, Adana and Mersin are rapidly urbanizing cities in the Mediterranean region of Turkey (Fig. 2).

We have slightly modified their original categories by considering city sizes, urban–rural characteristics in the stations, located in Mediterranean coastline of Turkey. Based on these considerations, the classification of stations and the number of stations within these classes are given in Table 3.

Table 3. Classification of Mediterranean coast stations (population size)

Population size	Classification	Station number	%
$\leqslant 20000$	Rural	1	4.2
$20000 \leqslant P < 100000$	Medium urban	9	37.5
$100000 \leqslant P < 500000$	Urban	10	41.7
$P \geqslant 500000$	Large urban	4	16.7

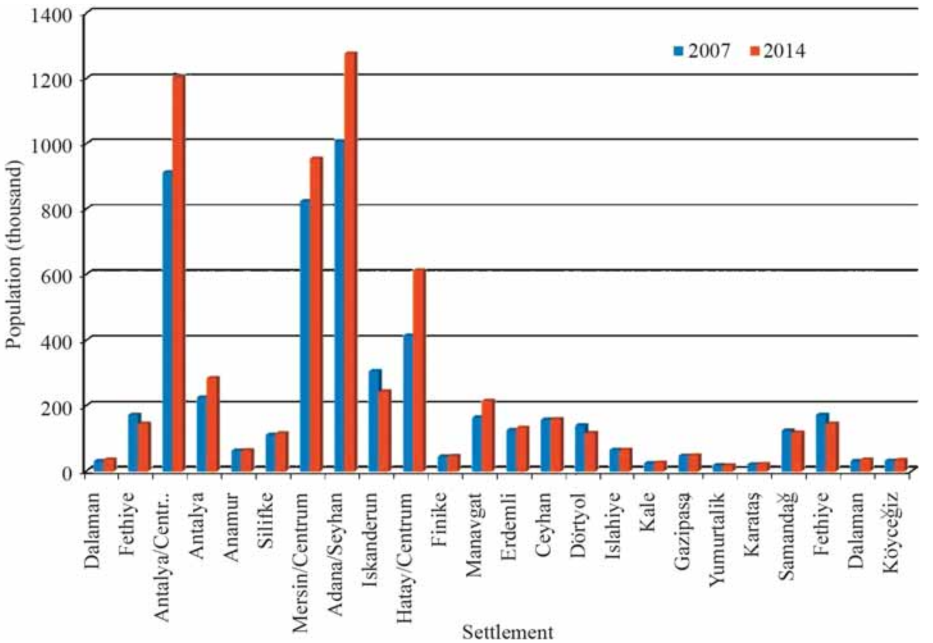


Fig. 2. Population of stations located in the Mediterranean region in 2007 and 2014 [TUIK, 2015].

One station is rural, 9 are medium urban, 10 and 4 settlements are respectively urban and large urban stations characterized by a high rate of population increase. The large urban stations (Antalya, Adana, Mersin, Hatay) constitute about 16.7 % of the total, which is the same based on both classifications. Most of the stations are very likely to have been affected by rapid urbanization, and thus subject to both urban heat island effects.

A set of 4 temperature indices related to the frequency of warm days (TX90), cold nights (TN10), warm spell duration index (WSDI) and cold spell duration index (CSDI) calculated for each station. In winter, low-frequency fluctuations increasing and non-significant decreasing trend are obtained in minimum temperatures. According to the result of test statistics obtained from the M-K rank correlation test, apparent increasing trends in winter minimum air temperature series are found to be statistically significant at 7 stations. Significant positive trends are evident over the highly urbanization areas in Turkey such as, Antalya and Mersin (Fig. 3).

In summer, increasing trends are obtained in maximum air temperatures all of the stations, except Adana and Ceyhan. Maximum temperatures have tended to increase in study area. These stations are located in touristic area of Turkey. Warming trends in the stations have shown approximately since the 1990s (Fig. 4).

Winter minimum extreme variability for the TN10 index is calculated and illustrated Mann-Kendall tests over Mediterranean coastline stations of Turkey. This index represents the number of days where minimum temperature is smaller than the 10th percentile of daily minimum temperatures during the period of data. The number of cold winter nights in Mediterranean coastline during the 1966–2014 with linear regression is present in figure 5. There has been generally decreasing rates in cold day frequency in winter. By the mid-1990s the extreme cold days display to increase progressively. As in figure 5, there is statistically decreasing trend at the beginning of 2013s (Fig. 5).

TX90 represents the number of days where TX is bigger than the 90th percentile of daily maximum temperature during the period of data. We identify that significant increasing trend in hot extremes in Mediterranean coastlines of Turkey. Our research results suggest that there are increases in hot days (TX90th) the period of 1966–2014. It is worthwhile to note that the frequency of cool day is relatively less with the areas of highest temperature recorded compared with the

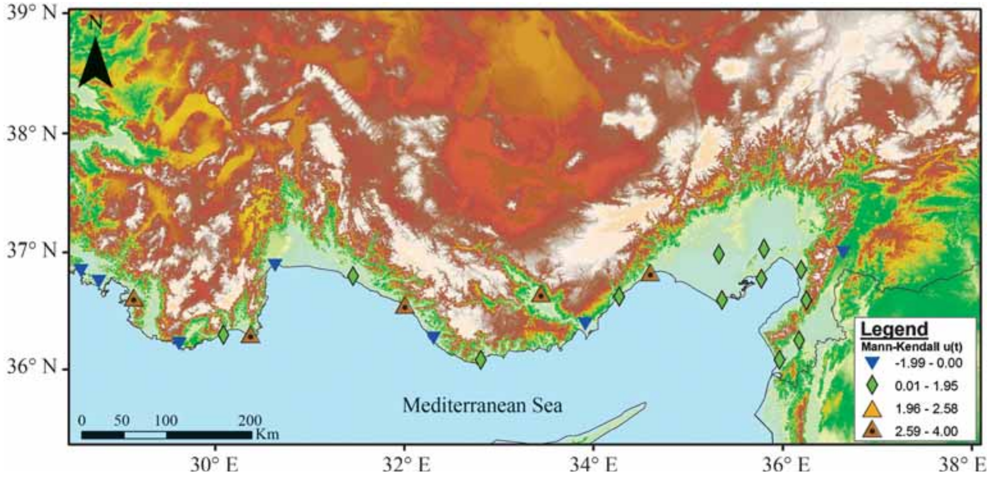


Fig. 3. Spatial distribution of winter minimum temperature trends of Mediterranean coastline of Turkey from Mann-Kendall test statistics *u*(*t*).

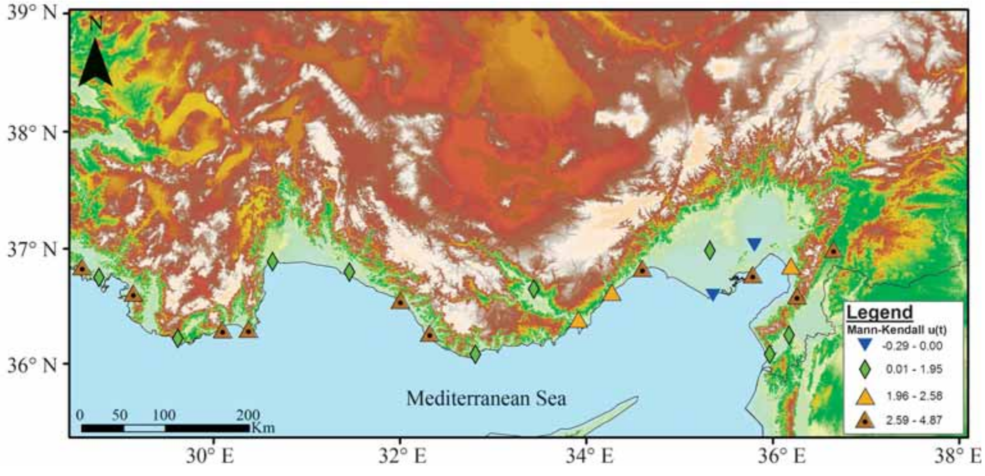
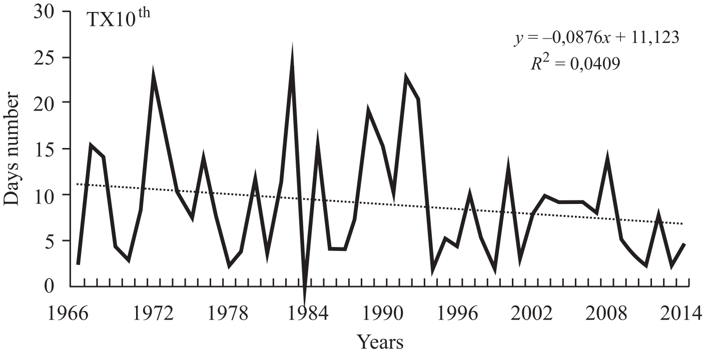


Fig. 4. Spatial distribution of summer maximum temperature trends of Mediterranean coastline of Turkey from Mann-Kendall test statistics *u*(*t*).

low temperature/high temperature in the Mediterranean coastline. The hot extremes ($TX90^{th}$) appear during the mid-1990s over the Mediterranean. Most of the warmest days experienced in Mediterranean coast line in 2012, 2007, 2008, 2010, 2000, 1998 and 2003, respectively. Hot day frequency appears for last decade (Fig. 6).



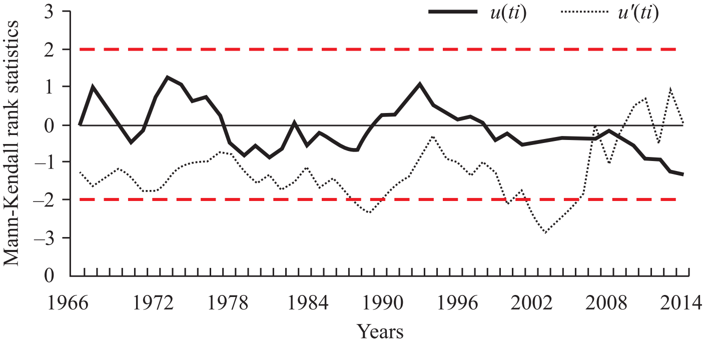


Fig. 5. $TN10^{th}$ temperature indices time series and Mann-Kendall statistics over Mediterranean coastline stations.

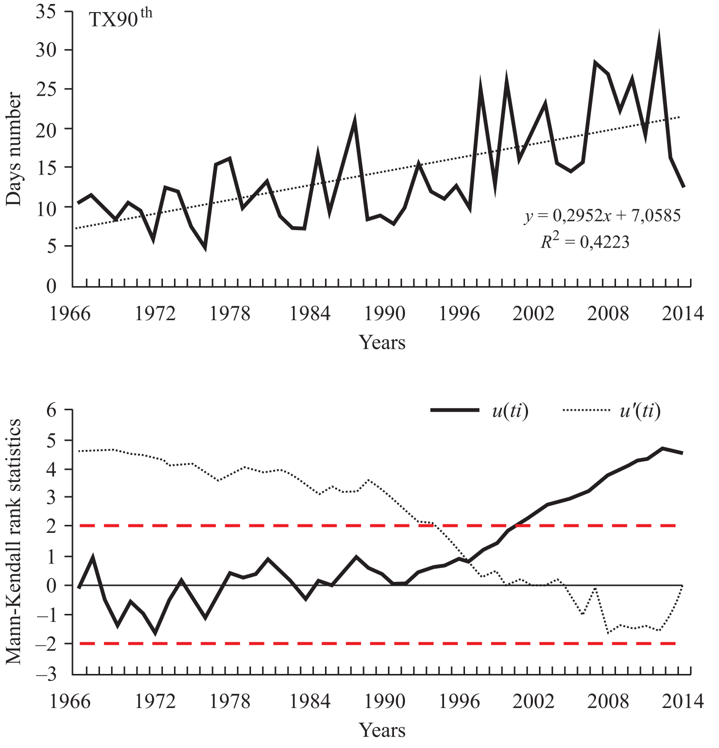


Fig. 6. TX90th temperature indices time series and Mann-Kendall statistics over Mediterranean coastline stations.

Our results indicate that cold spell duration in recent decades show a decreasing trend in over the Mediterranean coastline stations. The recent warming over the Mediterranean coastlines in winter is accompanied by an increase rather than a decrease in the cold spell duration. The pronounced warming between 2000 and 2014 is primarily associated with an increase the heat waves episodes over the Mediterranean and Middle East. At stations have been included a cold period of 1965–1990. But the stations show a decreasing trend in recent decades. In, 1967, the coldest year have experienced since records of the stations in Mediterranean coasts of Turkey. The most severe extreme cold years have experienced in 1972, 1990, 1967, 1992 and 1973, respectively. However, severe cold weather has been observed 1983, 1985, 1989, 1993, 1997, 2005 and 2008 in winter. Extreme cold spell has experienced in January and February 1967 and 1972, in December and January 1973, in January 1990 and the end of the January and beginning of the February in 1992 (Fig. 7).

WSDI represents the number of days with TX is greater than the 90th percentile of the daily maximum temperatures (least 6 consecutive days) occurring during the period. The frequency of summer warm spells shows increases throughout most in Mediterranean cost of Turkey. Mediterranean coast display a steady warm year, particularly from around 2000 onward. 2012, 2007, 1998, 2010 and 2000 years have experienced the hottest year, respectively (Fig. 8).

The 2003 summer season is a hot year on the Mediterranean coast but count of days under (e.g. 5 days İskenderun, Yumurtalık, Erdemli) or over 6 consecutive days (e.g. 14 days in Mersin, 15 days in Dörtyol). In this leads to the understanding that hot days haven't experienced in Mediterranean coast or less that happened.

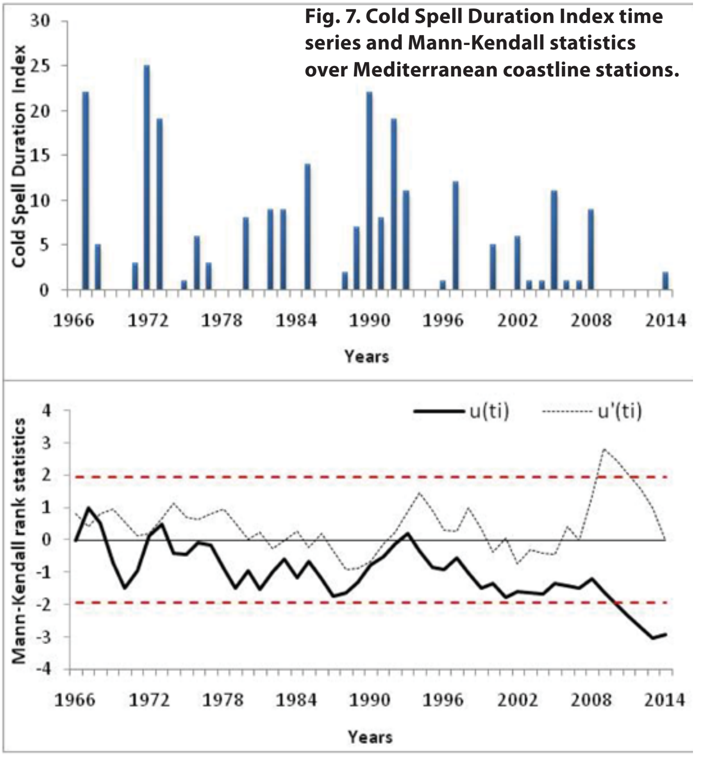


Fig. 7. Cold Spell Duration Index time series and Mann-Kendall statistics over Mediterranean coastline stations.

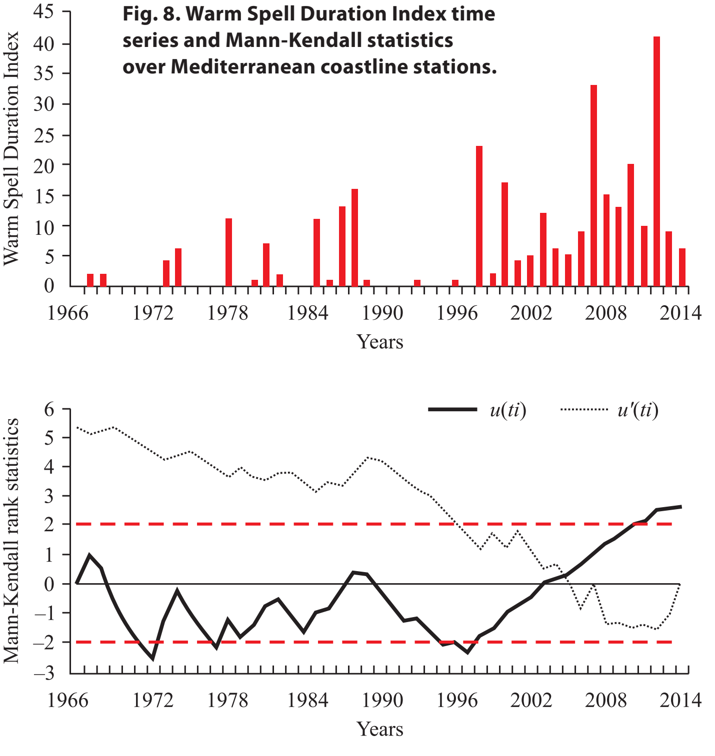


Fig. 8. Warm Spell Duration Index time series and Mann-Kendall statistics over Mediterranean coastline stations.

CONCLUSION

This research examines recent trends and variations in the frequency of winter cold and summer warm spell over Mediterranean coastline of Turkey. The threshold values were calculated for each station to determine the temperatures that were above and below the seasonal norms in winter and summer. According to these thresholds, especially summer and winter extremes in recent years, a significant increase in the number of hot days has been observed. similar to global and European trends [Perkins et al., 2012; Frich et al., 2002; Baldi et al., 2006; Unkasevic and Tosic, 2013]. Many of the aforementioned cold spell trends are generally not significant for the 1966–2008 periods. Stations display generally insignificant cold spell trends. Cold spells predominated until 1990, and afterwards, warm spells prevailed in study area.

In conclusion, there have been reductions in the frequency of winter cold spells decreased and increased in the frequency of warm spells over the Mediterranean coastlines of Turkey during the 1966–2014 periods. In addition, frequencies of cold spells decreased and warm spells toward increased may be a regional demonstration of rising temperatures in equatorial region and rapidly due to urbanization. Warm spells are expected to mostly follow summer mean warming in Mediterranean coastline of Turkey.

Trend in indices reflect an increase in both maximum and minimum temperature. Percentile based spatial change shows that the TN in winter will become warmer as the increase of TX in summer. The change in TX90 threshold temperature is higher than TN10 in study area. The occurrence of TN10 trend significantly decreases while for TX90 there is slight increase. The increasing trend in the TX90 is greater in magnitude. The occurrence of year to year cold spells trend significantly decreases while for warm spells there is slight increase. The increasing trend in the warm spells is greater in magnitude.

ACKNOWLEDGEMENTS

This work was supported by Research Fund of the Istanbul University, project number: UDP-55816. We acknowledge the Turkish State of Meteorological Office for providing the daily temperature data.

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Received 27.11.2015 **Accepted 25.01.2016**

DOI: 10.15356/2071-9388_01v09_2016_05

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