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# Climate Extreme Indices Derived from Observed Daily Temperature Data Over Three Cities of Thrace Region, Turkey

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**Abstract**
Construction industry can be affected by climate change in particular temperature and temperature extremes not only for the design phase but also for production or end-use/operation phases. In this regard the major climatic factors that are dominant for the building lifecycle must be evaluated. This study determined the 13-sector specific ET-SCI temperature indices annually and investigated their trend characteristics at Edirne, Kırklareli and Tekirdağ of Thrace Region for the historical period. The results showed a dominant increasing temperature trend over the region. Edirne, Kırklareli, and Tekirdağ stations showed significantly increasing trends for the hottest night, average daily maximum, and average daily minimum temperature indices in this study. Furthermore, the hottest day index also showed an increasing trend for all the stations with a significant trend for Edirne and Tekirdağ. Moreover, significant decreasing trends were observed in the heating degree days and increasing significant trends were observed for the SU (summer days), CDDCOLD18 (cooling degree days) and TR (tropical nights) values at all the stations.
***Keywords:*** Climate Change; Construction; Extreme Weather; Built Environment; Extreme Indices.

## 1. Introduction

Extreme weather conditions will become more severe and frequent due to climate change and temperature extremes can cause remarkable problems for energy demand, building design-management and affect many individual sectors in different ways (Toros, 2012; Li et al. 2015; Hatfield and Prueger, 2015; Berger and Worlitschek, 2019; Hoque and Yassaghi, 2019) so it became crucial to quantify and explore the effects of extreme events. Diagnosis of extreme-temperature patterns are particularly important because temperature effect many sectors. One of these sectors is the building construction which temperature has many applications. Moreover, construction industry can be affected by climate change in particular temperature and temperature extremes not only for the design phase but also for production or end-use/operation phases. For instance, considering the construction works and sites, risk factors such as extreme heat days or frost days may also cause delays and productivity decreases (Hayes, 2019). Moreover, energy performance of the buildings depends on the accurate design with the climate parameters (Lee et al, 2015). Building durability is another aspect that must be considered since degradation of building elements such as roof, fenestration, or insulation (Lacasse et al. 2020) can be faced. Frost damage, hygrothermal performance and solar effects of buildings and materials have been studied in various studies which temperature and temperature extremes are the main component of the effect (Saber et al. 2019; Nik et al. 2015; Andrady et al. 2011; Aarle van et al. 2015). The effect of climate change, in particular temperature and temperature extremes are expected to lead increasing costs, reduced service life and high cost of service such as heating or cooling.

To identify such effects over building construction, analyses conducted by different researchers in different countries to reveal the observed trend and the future conditions and define the potential effect. Wang et al (2018) stated that a climate risk index (CRI) is computed based on a sub-set of indices regarding water-logging, drought, high temperature, cryogenic freezing, and typhoon for China. Lee et al, 2015 also revealed the P and S indices of 24 cities over eight climate zones in the United States to use for the building envelope calculations. Roslan and Shafri (2018) used building climate data and revealed a building comfort index.

Yet there is no consensus on the definition of the extreme weather/climate event or indices. To address this issue The Expert Team on Sector-specific Climate Indices (ET-SCI) of World Meteorological Organization (WMO) indices have been used in this study.

It is crucial to have all the required information for decision makers to perform climate-change mitigation and adaptation strategies and policies. Turkey's annual mean temperature in 2019 was 14.7°C and this value is 1.2°C above from 1981-2010 normal (13.5°C) which made 2019 the fourth warmest year since 1971 according to State of the Climate in Turkey in 2019 report (Sensoy and Demircan, 2020). However, when extreme events are the subject of interest; regional and local scale studies become crucial to appropriately identify the characteristics of these extremes.

Three cities, namely Edirne, Kırklareli and Tekirdag of Thrace Region which represents the European side of Turkey were chosen for this study. Economic activities, that maes the region attractive also increases the anthropogenic stress besides natural effects (Bagdatli and Belliturk, 2016, Şaylan et al., 2011).

There are studies regarding extreme temperature and indices of Thrace Region, however this study deal with more sectoral perspective. The specific objectives of this study were to determine the values of 13 specific ET-SCI extreme indices that are effective for building design, construction, and operation by using the Climpact2 software at Edirne, Tekirdağ and Kırklareli of Thrace Region and to analyse the extreme temperature indices for the historical period.

## 2. Material and Methods

### 2.1. Study Area and Data

The Thrace region (Fig. 1) is in the north-western part of Turkey. Thrace Region of Turkey has borders with Greece and Bulgaria and Edirne, Kirklareli, Tekirdag, European sides of Istanbul and Canakkale are the provinces of the region. Effects of Black Sea and Balkans are dominant factors over the climate of the region (Sırdaş and Sen 2003).


**Figure 1.** Location of the stations

Daily historical data were provided by the Turkish State Meteorological Service (TSMS). Considering historical data, Station 17050, 17052 and 17056 daily observations were used for the historical-period calculations since it had a relatively sufficient length of data. Table 1 shows the details of the meteorological stations.

**Table 1.** Meteorological stations used in the study

| Station | Lon | Lat | Elevation (m) | Data Range |
|---|---|---|---|---|
| Edirne (17050) | 26.55 | 41.68 | 51 | 1952–2016 |
| Kırklareli (17052) | 27.21 | 41.74 | 232 | 1981–2016 |
| Tekirdağ (17056) | 27.50 | 40.96 | 4 | 1955–2016 |

### 2.2. Expert Team on Sector-specific Climate Indices (ET-SCI)

ET-SCI of the (WMO) have been widely used in many studies that intend to explore the climate trends and variability. Moreover, these indices also link the climatic changes and variability to sectoral impacts and the sensitivity of these sectors to observed and future variations (Herold et al. 2018; Junk et al. 2019). ClimPACT2 software is used to calculate the Expert Team on Sector-specific Climate Indices in this study (Zhang and Yang 2004; Alexander and Herold 2016). 1961 to 1990 period is the suggested standard reference period by World Meteorological Organization (WMO) for long-term climate change studies. In this study the baseline period was 1961-1990 for Edirne and

Tekirdağ stations, on the other hand because of the insufficient data, 1981-1990 period was used as the reference period for Kırıklareli station. The quality control of the time series was also tested with ClimPACT2 and the RHtests_dlyPrcp software packages.
After the required checks were completed, ClimPACT2 was run to calculate extreme temperature indices, shown in Table 2, from the daily temperature series.

**Table 2.** Explanation of Expert Team on Sector-specific Climate Indices (ET-SCI) used in this study

| ID | Name | Definition | Unit |
|---|---|---|---|
| TNX | Max TN Warmest daily TN | Hottest night | °C |
| TNN | Min TN Coldest daily TN | Coldest night | °C |
| TXM | Mean TX Mean daily maximum | Average daily maximum temperature | °C |
| TNM | Mean TN Mean daily minimum | Average daily minimum temperature | °C |
| TXX | Max TX Warmest daily TX | Hottest day | °C |
| TXN | Min TX Coldest daily TX | Coldest day | °C |
| ID | Ice Days Number of days when TX < 0 °C | Days when maximum temperature is below 0 °C | days |
| HDDHEAT18 | Heating degree days | Annual sum of *n* - *TM*, where *n* is a user-defined, location-specific base temperature and *TM* < *n*.. | |
| CDDCOLD18 | Cooling degree days | *Annual sum of* TM - n*, where* n *is a user-defined, location-specific base temperature and* TM > n | |
| SU | Summer days Number of days when TX > 25 °C | Days when maximum temperature exceeds 25 °C | days |
| DTR | Daily Temperature Range Mean difference between daily TX and daily TN | Average range of maximum and minimum temperature | °C |
| FD | Frost Days Number of days when TN < 0 °C | Days when minimum temperature is below 0 °C | days |
| TR | Tropical nights Number of days when TN > 20 °C | Days when minimum temperature exceeds 20 °C | days |

### 2.3. Trend Tests

The Mann–Kendall (MK) trend test is a widely used nonparametric test to determine the trend for a desired period and one of the most preferred tests for the hydrometeorological variables (Mann, 1945; Kendall, 1975; Gilbert, 1987; Nigussie and Altunkaynak, 2018; Wang et al., 2019; Militino et al., 2020). In this study the rank based Mann–Kendall trend test is also applied to temperature indices for the analyses period in order to capture the potential trends.
Furthermore, Innovative Trend Analyses (ITA) method (Şen, 2012) is used to visual inspection of trend and justify the MK test results. Details of this method can be found in (Şen, 2012, Güçlü, et al, 2018, Ali et al. 2019). In this method, two halves of time series are used in ascending order and drawn on the horizontal (X) and the vertical (Y) axis and the positions of the two halves relative to 1:1 line of the diagram are used to explore the trend characteristics of the whole time series. R package trendchange (Patakamuri, 2019) was used to perform the ITA analyses.

### 3. Results

MK trend test is conducted for the 13 temperature-based indices that were calculated in annual scale. Thirteen extreme-temperature indices were calculated from the daily temperature series of the observation periods at Edirne, Kırklareli and Tekirdağ Stations, Turkey. Moreover 6 daily extreme temperature indices, namely TNX, TNN, TXM, TNM, TXX, TXN (Hottest night, coldest night, avg. daily maximum temperature, avg. daily minimum temperature, hottest day, and coldest day)
Considering the daily temperature indices TNX, TNN, TNM and TXN indices, Tekirdağ station show the highest values. For TXM and TXX values the highest indices belong to Edirne Station. Considering the frequency indices, ID, SU, DTR, FD, CDDCOLD18 of Edirne station show the highest values and GSL and TR values of Tekirdağ station have the highest values among the others. The only index that is the highest among the others for Kirklareli is the HDDHEAT18 index. On the other hand, the standard deviation of these indices follows a different pattern compared with their mean values. For instance, TNX index has the highest standard deviation value at Kırklareli station while, TNN has its

highest standard deviation at Edirne station. Similar behaviour can be seen for the other indices. Furthermore, greater standard deviation values have been revealed from the TNN.

**Table 3.** Basic statistical parameters

| | min. | mean | sd | max. | cv | kurtosis | skewness |
|---|---|---|---|---|---|---|---|
| | | | | **TNX** | | | |
| **EDİRNE** | 20.10 | 22.01 | 1.15 | 24.60 | 0.05 | -0.81 | 0.27 |
| **KİRKLARELİ** | 20.00 | 22.92 | 1.54 | 25.90 | 0.07 | -0.87 | -0.01 |
| **TEKİRDAG** | 20.40 | 23.11 | 1.24 | 26.20 | 0.05 | -0.36 | 0.23 |
| | | | | **TNN** | | | |
| **EDİRNE** | -19.50 | -11.01 | 3.37 | -5.10 | 0.31 | -0.02 | -0.64 |
| **KİRKLARELİ** | -15.00 | -9.45 | 2.56 | -4.60 | 0.27 | -0.52 | -0.34 |
| **TEKİRDAG** | -12.30 | -7.26 | 2.65 | -2.10 | 0.37 | -1.05 | -0.02 |
| | | | | **TXM** | | | |
| **EDİRNE** | 17.97 | 19.66 | 0.88 | 21.83 | 0.04 | -0.40 | 0.43 |
| **KİRKLARELİ** | 17.64 | 19.01 | 0.93 | 21.17 | 0.05 | -0.86 | 0.55 |
| **TEKİRDAG** | 16.61 | 18.02 | 0.80 | 20.17 | 0.04 | 0.06 | 0.75 |
| | | | | **TNM** | | | |
| **EDİRNE** | 7.23 | 8.37 | 0.69 | 10.08 | 0.08 | -0.52 | 0.53 |
| **KİRKLARELİ** | 7.79 | 8.91 | 0.70 | 10.34 | 0.08 | -1.11 | 0.24 |
| **TEKİRDAG** | 9.27 | 10.43 | 0.73 | 12.06 | 0.07 | -0.69 | 0.55 |
| | | | | **TXX** | | | |
| **EDİRNE** | 34.50 | 37.96 | 1.99 | 44.10 | 0.05 | 0.00 | 0.42 |
| **KİRKLARELİ** | 33.70 | 37.63 | 2.19 | 42.50 | 0.06 | -0.69 | 0.20 |
| **TEKİRDAG** | 30.30 | 33.77 | 2.05 | 40.20 | 0.06 | 1.03 | 0.98 |
| | | | | **TXN** | | | |
| **EDİRNE** | -10.90 | -3.14 | 2.47 | 0.40 | 0.79 | 0.65 | -0.97 |
| **KİRKLARELİ** | -7.90 | -2.94 | 2.09 | 0.50 | 0.71 | -0.60 | -0.31 |
| **TEKİRDAG** | -6.10 | -1.13 | 2.14 | 2.90 | 1.89 | -0.69 | -0.39 |
| | | | | **ID** | | | |
| **EDİRNE** | 0.00 | 5.09 | 4.85 | 26.00 | 0.95 | 4.18 | 1.82 |
| **KİRKLARELİ** | 0.00 | 4.28 | 3.27 | 12.00 | 0.77 | -0.25 | 0.82 |
| **TEKİRDAG** | 0.00 | 1.95 | 2.35 | 9.00 | 1.20 | 1.06 | 1.35 |
| | | | | **HDDHEAT18** | | | |
| **EDİRNE** | 1715.00 | 2128.00 | 188.66 | 2609.00 | 0.09 | -0.41 | 0.00 |
| **KİRKLARELİ** | 1708.00 | 2140.00 | 201.28 | 2481.00 | 0.09 | -1.04 | -0.22 |
| **TEKİRDAG** | 1532.00 | 1929.00 | 179.00 | 2238.00 | 0.09 | -0.72 | -0.37 |
| | | | | **SU** | | | |
| **EDİRNE** | 101.00 | 130.80 | 10.91 | 159.00 | 0.08 | 0.26 | 0.20 |
| **KİRKLARELİ** | 101.00 | 120.40 | 11.93 | 147.00 | 0.10 | -0.81 | 0.31 |
| **TEKİRDAG** | 58.00 | 90.37 | 14.35 | 127.00 | 0.16 | -0.17 | 0.56 |
| | | | | **DTR** | | | |
| **EDİRNE** | 9.94 | 11.29 | 0.55 | 12.50 | 0.05 | -0.51 | 0.13 |
| **KİRKLARELİ** | 9.43 | 10.10 | 0.49 | 11.61 | 0.05 | 0.91 | 1.05 |
| **TEKİRDAG** | 7.04 | 7.59 | 0.31 | 8.47 | 0.04 | -0.22 | 0.64 |
| | | | | **FD** | | | |
| **EDİRNE** | 18.00 | 54.26 | 13.26 | 87.00 | 0.24 | 0.12 | -0.18 |
| **KİRKLARELİ** | 19.00 | 47.11 | 12.01 | 72.00 | 0.25 | -0.27 | -0.12 |
| **TEKİRDAG** | 4.00 | 24.08 | 9.94 | 51.00 | 0.41 | -0.22 | 0.36 |
| | | | | **CDDCOLD18** | | | |
| **EDİRNE** | 441.20 | 673.40 | 130.63 | 1098.00 | 0.19 | 0.48 | 0.82 |
| **KİRKLARELİ** | 481.20 | 663.80 | 120.65 | 935.20 | 0.18 | -0.80 | 0.48 |
| **TEKİRDAG** | 311.40 | 549.00 | 127.82 | 914.40 | 0.23 | 0.33 | 0.92 |
| | | | | **TR** | | | |
| **EDİRNE** | 1.00 | 8.62 | 8.17 | 37.00 | 0.95 | 2.59 | 1.66 |
| **KİRKLARELİ** | 0.00 | 14.64 | 11.04 | 43.00 | 0.75 | -0.03 | 0.82 |
| **TEKİRDAG** | 3.00 | 25.29 | 16.85 | 68.00 | 0.67 | -0.15 | 0.93 |

Furthermore, the trend patterns of daily temperature indices were investigated by ITA and Mann Kendall trend tests. 0.05-significance was chosen as confidence level for the MK trend test and significant and insignificant trend results of the nonparametric method was visually validated by the ITA method.

**Table 4.** MK test results of daily temperature indices

| | Edirne | | Kirklareli | | Tekirdag | |
|---|---|---|---|---|---|---|
| **Index** | **z value** | **p value** | **z value** | **p value** | **z value** | **p value** |
| TNX | 3.54 | 0.00 | 2.00 | 0.05 | 3.54 | 0.00 |
| TNN | 1.82 | 0.07 | -0.15 | 0.88 | 1.46 | 0.14 |
| TXM | 4.50 | 0.00 | 4.15 | 0.00 | 3.41 | 0.00 |
| TNM | 3.41 | 0.00 | 4.33 | 0.00 | 2.98 | 0.00 |
| TXX | 3.26 | 0.00 | 1.06 | 0.29 | 2.75 | 0.01 |
| TXN | 0.47 | 0.64 | -0.04 | 0.97 | 2.07 | 0.04 |

Considering daily temperature indices, TNX, TXM and TNM (hottest night, avg. daily maximum temperature and avg. daily minimum temperature) show significant increasing trend for all stations which indicate a significant increase in temperature. TXX (hottest day) show increasing trend for all stations but this increasing trend is significant for Edirne and Tekirdag stations. TXN (coldest day) index trend has a significant increase for Tekirdağ. However, it can be seen from the table that most of the indices show increasing trends whether significant or not. The only negative trend is seen from TNN (coldest night) and TXN (coldest day) indices of Kirklareli station, but these trend patterns are not significant, and the magnitude is not remarkable compared to others.

**Table 5.** MK test results of daily frequency temperature indices

| | Edirne | | Kirklareli | | Tekirdag | |
|---|---|---|---|---|---|---|
| **Index** | **z value** | **p-value** | **z value** | **p-value** | **z value** | **p-value** |
| ID | -0.75 | 0.45 | -0.15 | 0.88 | -1.68 | 0.09 |
| HDDHEAT18 | -2.85 | 0.00 | -3.42 | 0.00 | -2.30 | 0.02 |
| SU | 4.36 | 0.00 | 2.07 | 0.04 | 4.69 | 0.00 |
| DTR | 2.75 | 0.01 | 1.29 | 0.20 | 2.41 | 0.02 |
| GSL | 1.02 | 0.31 | 1.57 | 0.12 | 1.61 | 0.11 |
| FD | -0.70 | 0.49 | -1.36 | 0.17 | -0.78 | 0.43 |
| CDDCOLD18 | 5.03 | 0.00 | 4.51 | 0.00 | 4.74 | 0.00 |
| TR | 4.00 | 0.00 | 4.42 | 0.00 | 3.94 | 0.00 |

Statistically significant upward and downward trends were observed according to the MK test statistics. A significant decreasing trend in the HDDHEAT18 (heating degree days) values of all three stations were observed which means the need of the energy demand needed to heat a building decreases considering the observation period, whereas increasing significant trends were observed for the SU (summer days), CDDCOLD18 (cooling degree days) and TR (tropical nights) values at all the stations, DTR (daily temperature range) values at Edirne and Tekirdağ values. FD (frost days) and ID (ice days) showed decreasing trend for all the stations, but these are not statistically significant for the chosen significance level. Generally, insignificant negative trends were determined for low temperature extremes such as FD, ID, and significant decreasing trend for HDDHEAT18 whereas significant positive trends were identified for indices regarding temperature increase considering all stations. The results of the MK test results indicate a heating continuum over the observation period. On the other hand, FD and ID indices indicate that days with a minimum and maximum temperature below 0 °C increases insignificantly over the observation period.
Furthermore, daily temperature indices were analysed by the ITA method to determine the behaviour of the indices over time, to compare the MK trend test results and to make more precise inferences (Figure 2).

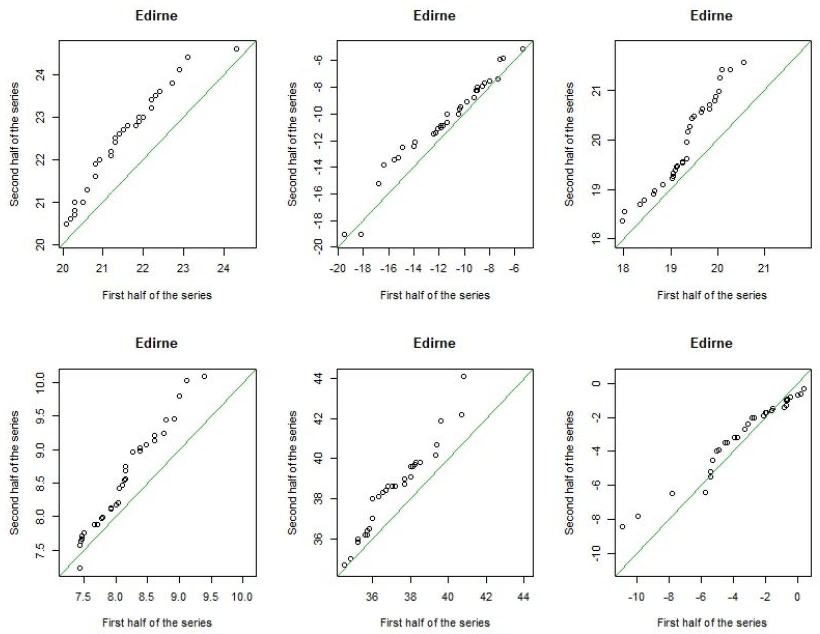


**Figure 2.** ITA Results of Daily Temperature Indices – Edirne (upper bound TNX, TNN, TXM and lower bound TNM, TXX, TXN respectively)

Edirne station data demonstrated significant increasing trend for all the daily temperature indices (TNX, TNN, TXM, TNM, TXX) except TXN. This behaviour is more obvious for TNX, TXM, TNM and TXX trend characteristics that was primarily driven by the high and medium data points of the annual values. The indices that exhibit statistically significant upward MK test results also revealed strong correlation with the ITA results. However, the negative trend behaviour was detected for the highest values of TXN index at Edirne station by the ITA results which most probably effect the low magnitude and the insignificance of MK test results regarding the TXN index.

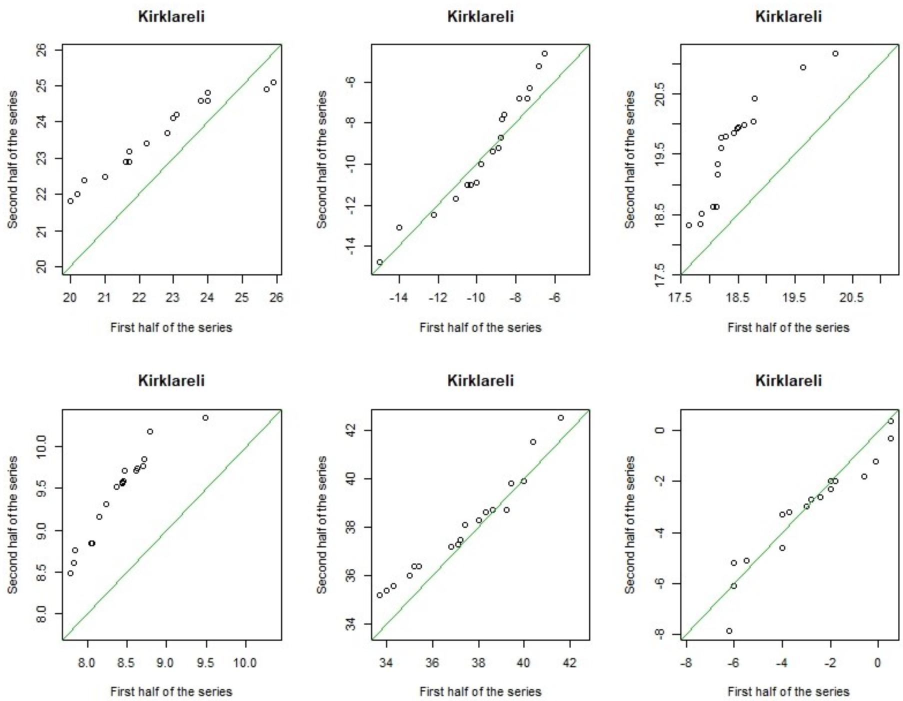


**Figure 3.** ITA Results of Daily Temperature Indices – Kırklareli (upper bound TNX, TNN, TXM and lower bound TNM, TXX, TXN respectively)

Kırklareli station showed a clear increasing trend for TNX (hottest night), TXM (avg. daily maximum temperature) and TNM (avg. daily minimum temperature) indices while the TNN (coldest night), TXX (hottest day) and TXN (coldest day) showed no significant trend tendencies. ITA results of Kırklareli station showed consistency for the indices with significant trends according to MK results while TNN and TXN indices showed insignificant decreasing trends for MK results which is not easy to infer from visually from the ITA results. These results confirm that Kırklareli station has an increasing temperature trend since average minimum and daily maximum values increase significantly and TNN and TXN showed insignificant decreasing trend.

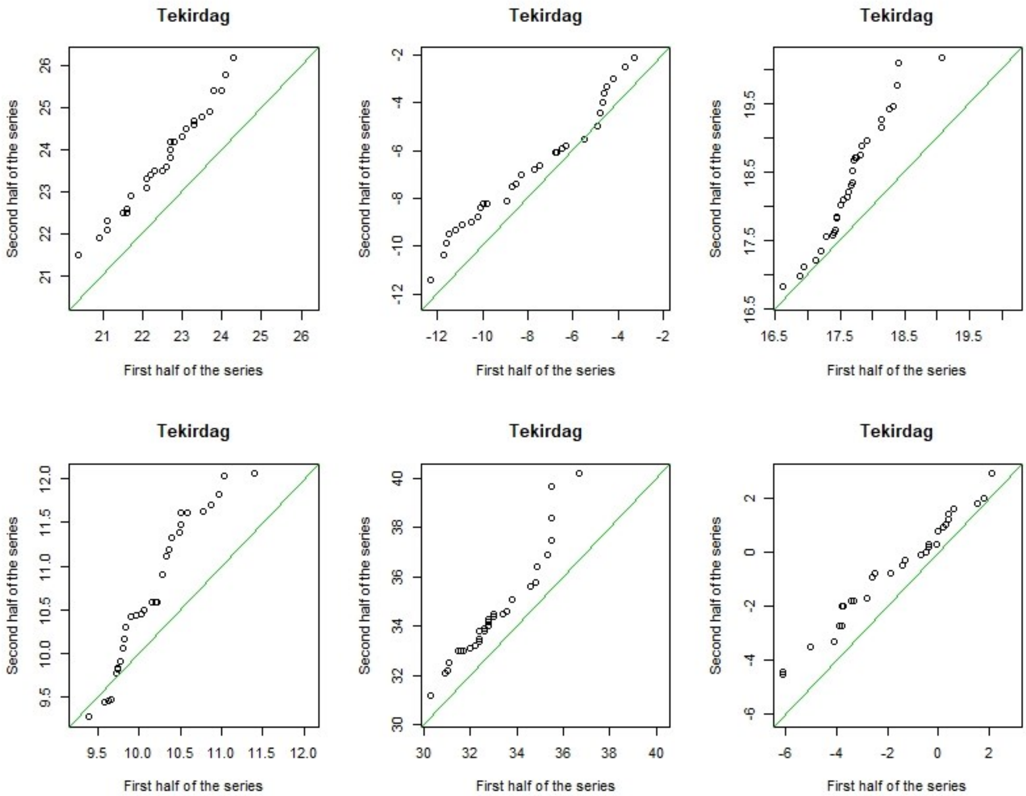


**Figure 4.** ITA Results of Daily Temperature Indices – Tekirdag (upper bound TNX, TNN, TXM and lower bound TNM, TXX, TXN respectively)

As the indices' trend revealed in Edirne station, Tekirdağ station indices also showed a clear increasing trend for all the daily temperature indices (TNX, TNN, TXM, TNM, TXX, TXN). This behaviour is more obvious for TNX, TXM, TNM and TXX. These behaviours also consistent with the MK test results. The significance of the trend behaviour was mainly driven by the high data points of the series considering the daily temperature indices. It can be concluded that visual inspection of the daily temperature indices generally showed consistent results with the results of nonparametric Mann Kendall trend test.

**4. Discussion and Conclusions**

This study determines the 13-sector specific ET-SCI temperature indices annually and investigated their trend characteristics at Edirne, Tekirdağ and Kırklareli of Thrace Region for the historical period. The results showed a dominant increasing temperature trend over the region. These results also consistent with the other studies over the globe and Turkey that researchers studied different regions of the globe to identify the characteristics of temperature extremes for observed and future periods.

In a recent study Nogueira et al. (2020) revealed a significant increase for the number of extreme hot days and nights, with nearly tripling the current value by 2070-2099 for Lisbon. Saddique et al. (2020) investigated the historical observations (1961–1990) and future period (2061–2090) in the Jhelum River Basin and revealed a warming trend in temperature indices at most of the stations of basin. Salameh et al. (2019) stated a significant warming trend for the last three decades for the Levant region. Fonseca et al. (2016) found increase in the number of warm days and warm nights over the Iberian Peninsula.

There are studies that investigated the spatial and/or temporal variability of temperature extremes. For instance, Sensoy et al. (2019) presented the risk over agriculture and water resources in their study regarding the sectoral climate indices for the Istanbul province of Turkey. Abbasnia and Toros, 2018 stated the influence of extreme warm days for the inland and metropolitan area stations. It is also found in thi study that number of summer days and number of tropical nights significantly increased over the study period. Acar et al. (2018) noted an increase in the frequency of hot and extremely hot days as of 1966-2014 period. Gönençgil and Acar Deniz (2016) determined

statistically significant trends for the warm spells over the Mediterranean coastline in Turkey. Edirne, Kırklareli and Tekirdağ stations also shoved significantly increasing trends for hottest night and average daily maximum temperature indices in this study. Furthermore, hottest day index also showed increasing trend for all the stations with significant trend for Edirne and Tekirdağ. Considering the magnitude of trend, the increasing tendency draws attention and reveals complementary results with previous studies. For instance, Erlat and Türkeş (2013) stated that the night-time air temperatures tended to increase rapidly beginning since the mid-1980s and revealed also that the night-time minimum air temperature regime or statistical distribution in Turkey changed evidently. In another study, it was concluded that the temperature regime changed significantly towards more temperate and warm conditions in Turkey, due to global warming, particularly after 1980s (Türkeş, 2012; Türkeş, 2013).
It is likely climate change have significant sectoral impacts. Certain regions over will face these impacts more severe and intense and became more vulnerable. Temperature extremes may be problematic for the design phase, construction phase and the operation phase of building. They may be problematic since the changing conditions expose the need to update the codes and standards that are effective in the insulation calculations, facade and window choice, wall thickness, materials, etc. Riahinezhad et al. (2019) stated that time of exposure to average and maximum temperatures is among the parameters that must be considered for aging methods and added the importance of site data for realistic test conditions and service life tests. Fernandes et al. (2019) focus on the service life prediction of wood, aluminium, and PVC window frames under real usage conditions and environmental data. Vandemeulebroucke et al. (2019) also mentioned the effect of climate change on the durability of the building envelope in their study that investigated the retrofitted solid masonry walls and historic buildings in the city of Ghent. The results of this study indicate the increasing temperature range between day and night times over the observed period. Also, the hottest night and day temperature also showed increasing trend. These changes over time will probably affect the material life too.
Moreover, extreme temperature (both cold and hot extremes) may cause disruptions in the construction phase, which in the end delay the expected time and induce time extension and/or additional cost. Lastly and more generally temperature extremes effect the indoor climate, thermal comfort, heating-cooling of the buildings that is also effective on the operational costs and energy efficiency. Baniassad and Sailor (2018) stated the strong relation between energy efficiency strategies on building resiliency and building characteristics with underlying climate. The results of this study draw attention to the significant increase in the cooling degree days which indicates a high need of cooling demand.

**5. Remarks**

It is now an urging issue that need attention with the evolving climatic conditions. Conditions such as increasing temperature, temperature range or freezing days may cause unexpected degradation of building parts and decrease the service life. Furthermore, insufficient analyses of the building cause energy loss or demand. In this regard the major climatic factors that are dominant for the building lifecycle must be evaluated to make proper decisions for the design, construction, and operational phases of buildings and update the performance criteria.

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**Conflict of interests**

The Author declares no conflict of interest.

**References**

Aarle van, M.; Schellen, H.; Schijndel van, J. (2015). Hygro Thermal Simulation to Predict Risk of Frost Damage in Masonry; Effects of Climate Change. Energy Procedia, 78, 2536–2541

Abbasnia, M.; Toros, H. (2018). Analysis of long-term changes in extreme climatic indices: A case study of the Mediterranean climate, Marmara Region, Turkey. Pure Appl. Geophys., 175, 3861–3873.

Acar, Z., Gönençgil, B., Korucu Gümüşoğlu, N. (2018). Long-term changes in hot and cold extremes in Turkey. Cografya Dergisi, 37, 57-67. https://doi.org/10.26650/JGEOG2018-0002

Alexander, L.; Herold, N. (2016). ClimPACT2 Indices and Software (R Software Package). Available online: https://htmlpreview.github.io/?https://raw.githubusercontent.com/ARCCSSextremes/climpact2/master/user_guide/ClimPACT2_user_guide.htm

Ali R, Kuriqi A, Abubaker S, Kisi O (2019) Long-Term Trends and Seasonality Detection of the Observed Flow in Yangtze River Using Mann-Kendall and Sen's Innovative Trend Method. Water 11: 1855

Andrady, A.L.; Hamid, H.; Torikaic, A. (2011). Effects of solar UV and climate change on materials. Photochem. Photobiol. Sci., 10, 292.

Bağdatlı, M.C., & Belliturk, K. (2016). Water Resources Have Been Threatened in Thrace Region of Turkey. *Advances in Plants and Agriculture Research, 4*.

Baniassadi, A., & Sailor, D. (2018). Synergies and trade-offs between energy efficiency and resiliency to extreme heat – A case study. Building and Environment, 132, 263-272.

Berger, M., Worlitschek, J. (2019). The link between climate and thermal energy demand on national level: A case study on Switzerland. Energy and Buildings, vol. 202, ID 109372, DOI:10.1016/j.enbuild.2019.109372.

Erlat, E. & Türkeş, M. (2013). Observed changes and trends in numbers of summer and tropical days, and the 2010 hot summer in Turkey. International Journal of Climatology, 33: 1898–1908.

Fernandes D., de Brito J., and Silva A. (2019). Methodology for service life prediction of window frames. Canadian Journal of Civil Engineering, 46(11).

Fonseca, D., Carvalho, M.J., Marta-Almeida, M., Melo-Gonçalves, P., & Rocha, A. (2016). Recent trends of extreme temperature indices for the Iberian Peninsula. *Physics and Chemistry of The Earth, 94*, 66-76.

Gilbert, R.O. (1987). Statistical Methods for Environmental Pollution Monitoring; Wiley: New York, NY, USA.

Gönençgil, B. & Acar Deniz, Z. (2016). Extreme maximum and minimum air temperature in Mediterranean coasts in Turkey. Russian Geogr. Soc., 9, 59–70.

Güçlü Y, Şişman E, Yeleğen M (2018) Climate change and FID curves. J. Flood Risk Manage, 11:S403-S418. https://doi.org/10.1111/jfr3.12229

Hatfield, J.L., & Prueger, J. (2015). Temperature extremes: Effect on plant growth and development. *Weather and climate extremes, 10*, 4-10.

Hayes S. (2019) Adapting Infrastructure to Climate Change: Who Bears the Risk and Responsibility?. In: Mathew J., Lim C., Ma L., Sands D., Cholette M., Borghesani P. (eds) Asset Intelligence through Integration and Interoperability and Contemporary Vibration Engineering Technologies. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-319-95711-1_24

Herold, N., Ekström, M., Kala, J., Goldie, J., & Evans, J. P. (2018). Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture. Weather and Climate Extremes, 20, 54–68. https://doi.org/10.1016/j.wace.2018.01.001

Junk, J.; Goergen, K.; Krein, A. (2019). Future Heat Waves in Different European Capitals Based on Climate Change Indicators. Int. J. Environ. Res. Public Health, 16, 3959.

Kendall, M.G. (1975). Rank Correlation Methods, 4th ed.; Charles Griffin: London, UK.

Lacasse, M.A., Gaur, A., & Moore, T. (2020). Durability and Climate Change—Implications for Service Life Prediction and the Maintainability of Buildings. *Buildings, 10*, 53.

Lee, D., Jo, J., Koo, S., & Lee, B. (2015). Development of Climate Indices Using Local Weather Data for Shading Design. *Sustainability, 7*, 1884-1899.

Li M, Shi J, Guo J, Cao J, Niu J, Xiong M (2015) Climate Impacts on Extreme Energy Consumption of Different Types of Buildings. PLoS ONE 10(4): e0124413. https://doi.org/10.1371/journal.pone.0124413

Mann, H.B. (1945). Non-parametric tests against trend. Econometrica, 13, 163–171.

Militino, A.F.; Moradi, M.; Ugarte, M.D. (2020). On the Performances of Trend and Change-Point Detection Methods for Remote Sensing Data. Remote Sens., 12, 1008.

Nigussie, T.A.; Altunkaynak, A. (2018). Impacts of climate change on the trends of extreme rainfall indices and values of maximum precipitation at Olimpiyat Station, Istanbul, Turkey. Theor. Appl. Clim., 135, 1501–1515.

Nik, V.M.; Mundt-Petersen, S.; Kalagasidis, A.S.; Wilde, P. (2015). Future moisture loads for building facades in Sweden: Climate change and wind-driven rain. Build. Environ., 93, 362–375.

Nogueira, M., Lima, D.C., & Soares, P. (2020). An integrated approach to project the future urban climate response: Changes to Lisbon's urban heat island and temperature extremes. *urban climate, 34*, 100683.

Patakamuri, S.K. (2019) trendchange: Innovative Trend Analysis and Time-Series Change Point Analysis; The R project for Statistical Computing: Vienna, Austria

Riahinezhad M., Eve A., Armstrong M., Collins P., and Masson J.-F. (2019). Field temperature and moisture loads from a building envelope as the basis for accelerated aging of barrier membranes. Canadian Journal of Civil Engineering, 46(11).

Roslan, S.N., & Shafri, H.Z. (2018). Developing building comfort index from building climate factors in a tropical urban environment.

Saber, H., Maref, W., & Hajiah, A. (2019). Hygrothermal Performance of Cool Roofs Subjected to Saudi Climates. *Frontiers in Energy Research, 7*.

Saddique, N., Khaliq, A. & Bernhofer, C. (2020). Trends in temperature and precipitation extremes in historical (1961–1990) and projected (2061–2090) periods in a data scarce mountain basin, northern Pakistan. Stoch Environ Res Risk Assess. https://doi.org/10.1007/s00477-020-01829-6

Salameh, A., Gámiz-Fortis, S., Castro-Díez, Y., Hammad, A.A., & Esteban-Parra, M.J. (2019). Spatio-temporal analysis for extreme temperature indices over the Levant region. *International Journal of Climatology, 39*, 5556-5582.

Sırdaş S, Sen Z (2003) Spatio-temporal drought analysis in the Trakya region, Turkey. Hydrol Sci J 48(5):809-820. https://doi.org/10.1623/hysj.48.5.809.51458

Sensoy, S., Demircan, M. (2019). State of the Climate in Turkey in 2019. Turkish State Meteorological Service. Url: https://mgm.gov.tr/eng/Yearly-Climate/State_of_the_Climate_in_Turkey_in_2019.pdf.

Şensoy, S., Kömüşçü, A., Ü., Türkoğlu, N., Çiçek, İ., Esentürk, H., (2020) Trends in Sectoral Climate Indices for Istanbul, 9 th International Symposium on Atmospheric Sciences (ATMOS 2019)

Şen, Z. (2012). Innovative trend analysis methodology. J Hydrol Eng 17:1042-1046.

Şaylan, L., Çaldağ, B., Bakanoğulları, F., Toros, H., Yazgan, M., Şen, O. and Özkoca, Y. (2011), Spatial Variation of the Precipitation Chemistry in the Thrace Region of Turkey. Clean Soil Air Water, 39: 491-501. doi:10.1002/clen.201000065

Toros, H. (2012), Spatio-temporal precipitation change assessments over Turkey. Int. J. Climatol., 32: 1310-1325. doi:10.1002/joc.2353

Türkes, M. (2012). Türkiye'de gözlenen ve öngörülen iklim değişikliği, kuraklık ve çölleşme. [Climate change, drought and desertification observed and predicted in Turkey]. Ankara Üniversitesi Çevrebilimleri Dergisi, 4 (2) , 1-32 . DOI: 10.1501/Csaum_0000000063

Türkeş, M. (2013). İklim Verileri Kullanılarak Türkiye'nin Çölleşme Haritası Dokümanı Hazırlanması Raporu [Report of Preparation of Desertification Map Document of Turkey by Using Climate Data]. Ankara: T.C. Orman ve Su İşleri Bakanlığı Çölleşme ve Erozyonla Mücadele Genel Müdürlüğü.

Vandemeulebroucke I., Calle K., Caluwaerts S., De Kock T., and Van Den Bossche N. (2019). Does historic construction suffer or benefit from the urban heat island effect in Ghent and global warming across Europe? Canadian Journal of Civil Engineering, 46(11).

Wang, Y.; Liu, G.; Guo, E. (2019). Spatial distribution and temporal variation of drought in Inner Mongolia during 1901–2014 using standardized precipitation evapotranspiration index. Sci. Total Environ., 654, 850–862.

Wang, Y., Song, L., Ye, D., Wang, Z., Gao, R., Li, X., Yin, Y., Wang, Z., & Liao, Y. (2018). Construction and Application of a Climate Risk Index for China. *Journal of Meteorological Research, 32*, 937-949.

Yassaghi, H.; Hoque, S. (2019). An Overview of Climate Change and Building Energy: Performance, Responses and Uncertainties. Buildings, 9, 166.

Zhang, X.; Yang, F. (2004). RClimDex (1.0) User Guide; Climate Research Branch Environment Canada: Ottawa, ON, Canada.