The spatial pattern of selected extreme precipitation indices for Turkey (1975-2012)

Faize Sarış 💿

Çanakkale Onsekiz Mart University, Department of Geography, Turkey Correspondence: Çanakkale Onsekiz Mart University, Department of Geography, Turkey. E-mail: faizesaris@gmail.com https://orcid.org/0000-0002-1721-4959

Abstract. This paper analyses extreme precipitation characteristics of Turkey based on selected WMO climate change indices. The indices - monthly total rainy days (RDays); monthly maximum 1-day precipitation (Rx1day); simple precipitation intensity index (SDII); and monthly count of days when total precipitation (represented by PRCP) exceeds 10 mm (R10mm) – were calculated for 98 stations for the 38-year overlapping period (1975-2012). Cluster analysis was applied to evaluate the spatial characterisation of the annual precipitation extremes. Four extreme precipitation clusters were detected. Cluster 1 corresponds spatially to Central and Eastern Anatolia and is identified with the lowest values of the indices, except rainy days. Cluster 2 is concentrated mainly on the west and south of Anatolia, and especially the coastal zone, and can be characterised with the lowest rainy days, and high and moderate values of other indices. These two clusters are the most prominent classes throughout the country, and include a total of 82 stations. Cluster 3 is clearly located in the Black Sea coastal zone in the north, and has high and moderate index values. Two stations on the north-east coast of the Black Sea region are identified as Cluster 4, which exhibits the highest values among all indices. The overall results reveal that winter months and October have the highest proportion of precipitation extremes in Turkey. The north-east part of the Black Sea region and Mediterranean coastal area from the south-west to the south-east are prone to frequent extreme precipitation events.

Key words: Extreme Precipitation Indices, Cluster Analysis, Climate Change, Turkey

Introduction

During the second half of the 20th century, a significant proportion of the global land area was increasingly affected by a significant change in precipitation, which was characterised by more frequent heavy rainfall and significant increases in the number of extreme precipitation events (Frich et al. 2002). The hydrological cycle was intensified by global warming, leading to more evaporation and precipitation (Arnell 1999). However, at the regional scale, some parts of the world experienced wetter conditions than before (Alexander et al. 2006). For the Mediterranean basin, which is a transition area between subtropical and mid-latitude regions, precipitation patterns show quite a variable character, and it is thus even more important to identify the impact of climatic changes. Mediterranean countries are mainly dominated by regular dry conditions during the hot season and repeated periods of drought or extreme precipitation events during late autumn and winter (Oikonomou et al. 2008). According to Paxian et al. (2015), the Mediterranean basin will experience strong summer and winter drying over the northern and southern Mediterranean, respectively. However, precipitation extremes are tending to increase in even more Mediterrane-



[©] Author(s) 2020. This work is distributed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (http://creativecommons.org/ licenses/by-nc-nd/4.0/).

Faize Sarış

an areas, implying regions with decreasing totals but intensifying extremes, e.g. southern Europe and Turkey in winter and the Balkans in summer (Paxian et al. 2015). The results for different areas across the Mediterranean region show considerable regional differences in precipitation indices over the larger region (Nastos et al. 2013). Therefore, regional scale studies are becoming more and more important for Mediterranean countries in an area considered to be a hotspot of future climate crisis.

Due to its location between the subtropical and mid-latitude zones, the Azores (high) and the Iceland (low) strongly influence Turkey's climate and precipitation regime. Turkey is affected by Polar and Tropical air masses in winter and summer, respectively. The cP (continental Polar) is a continental, cold, dry air mass that originates from Siberia and generates orographic rains if it becomes saturated while crossing the Black Sea (Akçar et al. 2007). The mP (marine Polar) air mass originates from the Atlantic Ocean and travels across Europe and the Balkans. It becomes unstable over Turkey and causes rainfall in coastal areas (Black Sea and Marmara), and snowfall at higher elevations and in the inner parts of the country. The transport of mP air into the Mediterranean basin creates the Mediterranean cyclogenesis and Mediterranean air mass, which also prevail in western and southern parts of Anatolia. In combination with the local orographic conditions, the Mediterranean air mass produces a considerable amount of precipitation. The Mediterranean trajectory of mP is more effective than the Atlantic trajectory in terms of generating rainfall (Tatli et al. 2004). Turkey's precipitation regime character is shaped by: (1) large-scale atmospheric circulation during the winter months for coastal regions of Marmara, the Black Sea, the Aegean and Mediterranean regions; and (2) convectional rainfall for interior regions that experience a rainy spring. Turkey's physiographic character has a major influence on its precipitation regimes. High relief and continentality play an important role in causing a rainfall deficit for interior regions; also, where mountains are located along the coast, there is high precipitation, particularly in winter (Sariş et al. 2010).

For Turkey, it has been demonstrated by several researchers that the monthly, seasonal and annual precipitation totals indicate significant changes both in space and time (Türkeş 1996 and 1998; Sen and Habib 2000; Kadioğlu et al. 1999; Tatli et al. 2004; Partal and Kahya 2006; Türkeş et al. 2008a; Sariş et al. 2010; Raja et al. 2017). Important decreasing trends in annual and winter precipitation totals are highlighted over western and southern coastal regions of Turkey. Yeşilırmak and Atatanır's (2016) study on precipitation concentration over Turkey analysed daily precipitation data and found higher values of Daily Precipitation Concentration Index in north-western and southern parts, and lower values in western-central, central, eastern and north-eastern parts, and that the southern part was the most critical part of Turkey, with the highest values of precipitation concentration and annual total precipitation but the lowest number of rainy days. Regional studies over the western and southern part of Turkey has shown that dry periods are prolonged (Çelik 2019) while, on the other hand, heavy rainfall events tend to be more frequent. For example, Yılmaz (2015) stated that Antalya (southern Turkey) haves the potential to experience more intensive rainfalls in the future, which may lead to floods. Şensoy et al. (2013) have analysed extreme climate events over Turkey. For precipitation they revealed that numbers of heavy precipitation days have been increasing at most stations except the Aegean and south-eastern Anatolia, and usually cause extreme flood events. The maximum one-day precipitation has been increasing at most of the stations except in south-eastern Anatolia.

The observed trends in intensity and frequency of extreme precipitation events must be taken into account in order to improve the management of water resources. Therefore, it is very important to evaluate past changes in extreme precipitation events together with the current status in order to present perceptible and explicable spatiotemporal variation patterns of Turkey's precipitation climatology. This effort will lead to further regional-scale studies which are becoming critical for a country like Turkey with its vast regional discrepancies. This paper aims to present the variability patterns (spatial and intra-annual) in precipitation extremes by analysing changing conditions in the selected indices for Turkey. The following procedure is adopted to be able to clarify characteristics of extremes for the period 1975-2012. In particular, for each station and for each year: (i) (RDays) Monthly toFaize Sarış

tal rainy days, (*Rx1day*) Monthly maximum 1-day precipitation, (*SDII*) Simple precipitation intensity index, and (*R10mm*) Monthly count of days when PRCP \geq 10 mm were calculated; (ii) cluster analyses were applied to classify precipitation extremes throughout Turkey; and (iii) intra-annual variability of precipitation extremes was identified (box-and-whisker plots). Providing a contribution to understanding the extreme precipitation character and variation patterns over Turkey is the overall objective of this study.

Data and method

Daily precipitation totals for 98 Turkish State Meteorological Service stations were used; station selection was based upon record length and the aim to provide optimal spatial coverage across Turkey. A 38-year overlapping period for daily precipitation records from 1975 to 2012 was used. The metadata of the stations are listed in Table 1.

Climate index calculations

The indices of the World Meteorological Organization–Commission for Climatology (WMO–CCL) and the Research Programme on Climate Variability and Predictability (CLIVAR) were adopted for identifying precipitation extreme characteristics (Peterson et al. 2001; Klein Tank and Können, 2003). Daily records were used in order to calculate time series of precipitation extremes at monthly and annual scales. The selected extreme precipitation indices are as follows:

- RDays, Monthly total rainy days
- *Rx1day*, Monthly maximum 1-day precipitation:

Let RR_j be the daily precipitation amount on day *i* in period *j*. The maximum 1-day value for period *j* is:

Rx1dayj = max (RRij)

• *SDII*, Simple precipitation intensity index:

Let *RRwj* be the daily precipitation amount on wet days, w (*RR* \ge 1*mm*) in period *j*. If *W* represents number of wet days in *j*, then:

$$SDII_j = \frac{\sum_{w=1}^W RRwj}{W}$$

• *R10mm*, Monthly count of days when PRCP≥10mm, where PRCP is the total precipitation measured as water equivalent:

Let *RRij* be the daily precipitation amount on day *i* in period *j*. Count the number of days where: $RRij \ge 10mm$

Cluster Analysis

Cluster analysis is a data reduction method based on grouping a set of data into object clusters. Cluster analysis is widely used in climatology research and in this study it was evaluated for classifying precipitation extremes by considering their magnitude. The classification procedure, based on magnitude characteristics, was developed by Hannah et al. (2000) and has been adopted in several studies (Harris et al. 2000; Bower et al. 2004; Kansakar et al. 2004; Hannah et al. 2005). For Turkey, Ünal et al. (2003), Sariş et al. (2010) and İyigün et al. (2013) have applied cluster analysis to precipitation data at the national scale. In this study, the classification procedure starts with the calculation of annual series of four indices (RDays, Rx1day, SDII, R10mm) for each station, regardless of their timing. Standardised z-score values of stations were preferred for inputting into the analysis in order control for differences in their relative values. The magnitude classification was performed by hierarchical, agglomerative cluster analysis using Ward's method. Ward's method typically outperforms other algorithms in terms of the separation to give relatively dense clusters with small within-group variance (Griffith and Amrhein 1997; Yarnal 1992). The dendrogram structure and agglomeration schedule (scree) plot that shows the breaks of slope was evaluated to determine the appropriate number of clusters for homogeneous classification. Thus, each

Name Name Name Name Lentsh (N) (E) (ma.sl.) Adara 7751 73 37.00 35.33 27 Ipsala 17622 64 4093 26.00 1 Adigian 17099 65 39.72 43.05 1622 Ispain 17666 50 40.48 41.00 1222 Akhari 17184 66 38.92 27.85 93 Izmir 17725 49 37.00 35.03 57.2 Ansary 17384 64 38.33 34.00 965 Kahamanmarg 17755 49 37.00 36.03 22.03 177.5 Anara 17105 67 40.65 32.83 44 Karas 17064 63 41.37 33.20 100.7 Anara 17160 65 40.17 27.9 122 162.4 177.6 166 43.73 38.40 103.7 Anara 17160 57 41.18	Station	Station	Data	Latitude	Longitude	Altitude	Station	Station	Data	Latitude	Longitude	Altitude
Adam 1731 73 37.00 35.33 27 Ipsala 17622 64 40.93 26.40 10 Adiyanan 17265 65 37.75 38.28 672 iskenderun 17370 63 36.58 36.17 4 Adiyanan 17265 65 37.75 38.28 50.01 17220 65 38.43 27.17 25 Akaray 17384 64 38.83 34.08 965 Kahamanmang 17922 66 37.18 33.22 1025 Anaaya 17085 67 40.65 35.83 412 Kataman 17922 66 37.18 33.22 1025 Anakaya 17384 64 36.58 891 Kataman 17922 66 37.13 33.78 80.0 Anakaya 17984 62 36.02 36.17 10.0 Kayatai 17025 71 31.62 37.1 63.8 40.47 22.65 1033	Name	Number	Lentgh	(N)	(E)	(m a.s.l.)	Name	Number	Lentgh	(N)	(E)	(m a.s.l.)
Achigama172656537.7538.2867.2bisemeteru17.706336.5836.104Adhinar17.1846638.9227.8593Lizmir17.2206538.4327.1012.22Akanary17.846438.3834.08965Kahamanmangi17.2554937.6036.3057.2Anaraya17.0306730.6035.83412Karanaran17.0987340.6243.1017.75Anlana17.1307339.9532.88891Kastamoru17.0747341.3733.78800Anlana17.1306541.1242.7218.29Kiklareli17.0527041.7322.23232Arahan17.6306541.1242.7218.29Kiklareli17.0527041.7322.8310.33Argin17.247237.555556Kizlachamarn17.664640.4722.6310.33Bardina17.625741.1841.82628Kizlachamarn17.0666540.7829.9376Bardina17.227339.4229.9796996910.402grit17.7907339.4229.97969Birghi17.027340.2540.2315.84Kizlachamarn17.7907339.6222.955Bodrum17.297330.7335.8230.0417.79 </td <td>Adana</td> <td>17351</td> <td>73</td> <td>37.00</td> <td>35.33</td> <td>27</td> <td>Ipsala</td> <td>17632</td> <td>46</td> <td>40.93</td> <td>26.40</td> <td>10</td>	Adana	17351	73	37.00	35.33	27	Ipsala	17632	46	40.93	26.40	10
Ağı 17099 65 39.22 42.05 1622 bpri 17666 50 40.48 27.17 25 Aksarey 17844 64 38.38 34.08 965 Kahramarınarını 17255 49 38.43 27.17 25 Annayur 17085 67 40.65 35.83 412 Karaman 17325 69 37.18 33.22 1025 Annayur 1730 73 39.95 32.88 891 Karsen 17098 73 40.62 43.010 77.5 Antalya 17320 57 41.12 42.27 1829 Kirklereii 17052 70 41.73 27.25 22.2 Kirklereii 17052 70 40.72 40.25 40.23 17.27 53.9 20.9 Kirklereii 17075 47 37.82 27.25 22.2 45 37.87 27.25 22.2 45 37.42 2.939 969 Bardian 17120 70<	Adiyaman	17265	65	37.75	38.28	672	Iskenderun	17370	63	36.58	36.17	4
Ahltar 17184 66 38.92 27.85 93 Lmir 17220 65 88.40 27.17 25 Aksaray 17836 67 40.65 35.83 412 Karaman 17255 49 37.60 37.18 33.20 1725 Anmaya 17320 59 36.08 32.83 4 Karam 17094 73 40.62 31.01 1775 Ankara 17190 73 39.95 32.88 891 Karaman 17047 73 40.62 32.81 103 Antahan 17630 65 41.12 42.72 18.29 Kirikareli 17052 70 41.33 33.54 1033 Andhan 17630 65 41.157 35.92 22.05 Kotaeli 17064 46 40.42 32.5 22.2 38.95 38.32 948 Bardimi 17232 45 38.85 40.42 17.178 48 39.15 43.33 <	Ağri	17099	65	39.72	43.05	1632	Ispir	17666	50	40.48	41.00	1222
Aksay 17834 64 38.38 34.08 965 Kahranmaray 17252 649 37.08 36.93 572 Ananya 17085 67 40.65 35.83 412 Karaman 17932 66 37.18 33.22 1025 Ananya 1730 73 39.95 32.88 891 Kastemonu 17074 73 41.37 32.78 800 Antakya 17630 65 41.12 42.72 1829 Kirikareli 17052 70 41.33 22.25 1033 Ardian 17224 72 37.85 27.85 55 Kilis 17078 71 66.72 37.12 63 83.22 968 Bardim 17122 70 40.15 29.98 539 Malaya 17199 72 38.35 38.22 948 Birgio 17120 74 40.35 0.52 150 Marayat 17199 72 38.35 38.22 <	Akhisar	17184	66	38.92	27.85	93	Izmir	17220	65	38.43	27.17	25
Anagay 17085 67 40.65 35.83 412 Karan 17922 66 37.18 33.22 1025 Anamur 17220 59 36.08 32.83 4 Kars 17094 73 40.62 41.37 33.78 800 Antaya 17984 62 36.0 36.17 100 Kastamonu 17064 66 38.73 35.48 1003 Ardahan 17630 65 41.12 42.72 182.9 Kirakareli 17064 46 0.40 32.65 1033 Ardin 17234 72 37.85 55 Kirakeli 17074 73 40.47 22.55 22 Barloim 1722 70 40.55 27.97 58 Koraeli 17066 65 40.78 27.25 22 Barjourt 17266 63 37.72 30.28 40.48 1177 Malazgit 171790 48 38.32 948 Bing	Aksaray	17834	64	38.38	34.08	965	Kahramanmaraş	17255	49	37.60	36.93	572
Anamur 17320 59 26.08 22.83 4 Kastamonu 1704 73 40.62 43.10 1775 Antakya 17130 73 39.95 32.88 891 Kastamonu 17044 73 40.62 43.10 1775 Antakya 17130 65 41.12 42.72 1829 Kiklareli 17052 70 41.73 22.32 22.3 Artvin 17045 57 41.18 41.82 62.8 Kailachamam 17664 46.4 46.4 46.4 32.65 1033 Aydin 17224 72 37.95 27.35 56 Kiiachya 17729 73 39.42 22.97 959 Bandirma 17114 57 40.15 29.38 539 Molazy 17129 73 39.42 22.97 959 Biecki 17122 63 37.72 27.43 26 Marayat 17954 57 36.78 31.43 38	Amasya	17085	67	40.65	35.83	412	Karaman	17932	66	37.18	33.22	1025
Antakya 17130 73 9395 32.88 891 Kastamonu 1704 73 41.37 33.78 800 Antakya 17984 62 362.0 36.17 100 Kiyaseii 17196 66 36.37 35.48 1093 Ardahan 17664 62 36.20 36.12 42.22 12.2 12.2 4.23 12.2 32.2 32.2 35.8 1033 35.48 1093 Aydin 17234 72 37.85 27.85 56 Kils 17978 71 36.62 40.72 37.2 23.2 Baydut 17686 73 40.25 40.23 1584 Kugadasi 17232 45 37.8 38.2 94.9 Bilock 1723 43 38.88 40.48 1177 Malaya 17980 48 39.15 42.53 1565 Bordur 17230 63 37.72 30.28 967 Maniya 174.04 3	Anamur	17320	59	36.08	32.83	4	Kars	17098	73	40.62	43.10	1775
Antakya 17984 62 36.20 36.17 100 Kayseri 17196 66 38.73 35.48 1093 Ardnan 17630 65 41.12 42.72 1829 Kinklareli 17052 70 41.73 27.23 232 Ardin 17234 72 37.85 27.85 56 Kinklareli 17066 65 40.47 32.2 638 Bardima 17622 50 41.57 35.92 20 Kocaeli 17066 55 40.27 22.52 22 Bayburt 17668 73 40.25 40.23 1584 Kutaday 17725 73 39.42 29.97 969 Biedati 17122 70 40.15 29.98 539 Malayat 17190 73 38.62 27.43 71 Bodrum 17220 63 37.72 30.28 967 Marayat 17954 57 36.78 31.43 38 Bodrum 17206 53 36.53 3.29 968 Marayat 17186	Ankara	17130	73	39.95	32.88	891	Kastamonu	17074	73	41.37	33.78	800
Andahan176306541.1242.721829Kinklarella170527041.7327.23232Artvin170455741.1841.82628Kizilcahamam176644640.4732.651033Aydin172247237.8527.8556Kizilcahamam170666540.7829.9376Bandima171145740.2527.9758Kuzaqaasi172324537.8727.2522Bigbut171667340.2540.231584Kutahy177257339.4229.97969Bileck171227040.1529.98539Malarya171997238.3538.32948Bingoi172096637.0527.4826Manaryat177867336.6227.4371Ceyhan179805137.0527.4826Marrin172566437.3040.731050Cihanbeyli170805138.6332.92968Merrin172566437.3040.731750Cahakkal171126640.152.6426Merrin172806840.8735.33755Cahakkal171206640.152.6426Merrin17386840.8735.33755Cahakkal171205540.6033.62751Mugla172207338.622.84 <t< td=""><td>Antakya</td><td>17984</td><td>62</td><td>36.20</td><td>36.17</td><td>100</td><td>Kayseri</td><td>17196</td><td>66</td><td>38.73</td><td>35.48</td><td>1093</td></t<>	Antakya	17984	62	36.20	36.17	100	Kayseri	17196	66	38.73	35.48	1093
Artvin 17045 57 41.18 41.82 628 Kizlicahamam 17664 46 40.47 32.65 1033 Aydin 17234 72 37.85 27.85 56 Kilis 17978 71 36.22 37.12 638 Baña 17114 57 40.35 27.97 58 Kutahya 17725 73 39.42 29.97 969 Bileck 17122 70 40.15 29.98 539 Malatya 17795 73 39.42 29.97 969 Bileck 17122 70 40.15 29.98 539 Malatya 17780 48 39.15 42.53 1565 Bodum 17203 63 37.72 30.28 967 Manisa 17186 73 36.20 74.3 71 Ceyhan 17800 55 36.27 75 Mula 17247 73 37.22 28.37 646 Cankika 17102	Ardahan	17630	65	41.12	42.72	1829	Kirklareli	17052	70	41.73	27.23	232
Aydin172347237.8527.8556Kilis179787136.7237.126.38Bardiuma171415740.3527.9758Kusadasi172324537.8722.9376Baybut176867340.2527.9758Kusadasi172324537.8722.97969Bileck171227040.1529.98539Malarya177197238.3538.32948Bingiol172034338.8840.481177Malarya177804839.1542.531565Bodrum172906637.0527.4326Manarayat179657336.6227.4371Ceyhan179607037.0335.8230Marcin172756437.0040.731050Canakkale171126640.1526.426Merzifon170836840.8735.33755Cankini170005540.6033.62751Mugla172227337.2228.37646Cernigacek177686439.0736.92953Mug172145338.6832.1586Corlu170846330.0726.426Merzifon170335240.9832.1586Corlu170847340.5534.95776Ordu170335240.8431.11121<	Artvin	17045	57	41.18	41.82	628	Kizilcahamam	17664	46	40.47	32.65	1033
Baria 17622 50 41.57 35.92 20 Kocaeli 17066 65 40.78 29.93 76 Bandium 17114 57 40.35 27.97 58 Kugadasi 17222 45 37.87 27.25 22 Bingi 17266 73 34.27 40.25 40.23 1584 Kurahya 17719 73 39.42 29.97 969 Bingi 17203 43 38.88 40.48 1177 Malazyat 17780 48 39.15 42.53 1555 Bodrum 17280 63 37.27 30.28 967 Manavgat 17954 57 38.62 7.43 171 Cyankine 17800 71 33.52 30 Marcin 17320 73 38.62 27.43 71 Cyankini 17080 55 40.60 33.62 751 Mugla 17222 73 37.22 28.37 646 Cyankin </td <td>Aydin</td> <td>17234</td> <td>72</td> <td>37.85</td> <td>27.85</td> <td>56</td> <td>Kilis</td> <td>17978</td> <td>71</td> <td>36.72</td> <td>37.12</td> <td>638</td>	Aydin	17234	72	37.85	27.85	56	Kilis	17978	71	36.72	37.12	638
Bandirma 17114 57 40.35 27.97 58 Kuşadasi 17232 45 37.87 27.25 22 Baybut 17786 73 40.25 40.23 1584 Kutalnya 17725 73 39.42 29.99 969 Bilecik 17122 70 40.15 29.98 539 Malary 17190 48 39.15 42.53 1565 Bordum 17203 63 37.72 30.28 967 Manisa 17186 73 36.62 27.43 71 Ceyhan 17960 70 37.03 38.82 30 Marrin 17340 73 36.60 34.00 3 Canhabeyli 17080 51 38.65 32.93 Matin 17240 73 36.60 3<.75 Gankale 17112 66 40.15 26.42 6 Merzin 17030 73 34.68 1201 Grankale 17112 66 41.1	Bafra	17622	50	41.57	35.92	20	Kocaeli	17066	65	40.78	29.93	76
Baybutt 1768 73 40.25 40.23 1584 Kütahya 17725 73 39.42 29.97 969 Bileck 17122 70 40.15 29.98 539 Malaya 17199 72 38.35 38.32 948 Bingol 17203 43 38.88 40.48 1177 Malazgitt 17780 46 31.43 38 Burdur 17236 63 37.72 30.28 967 Manisa 17186 73 36.62 27.43 71 Ceyhan 17960 70 37.03 55.82 30 Marcin 17730 63 34.60 33 63 34.60 33 64 40.77 55.33 75 Garukia 17080 54 40.60 34.20 751 Mugla 17220 63 38.73 44.48 120 Gariu 17054 64 40.07 34.95 776 Ordu 17033 52 40.98	Bandirma	17114	57	40.35	27.97	58	Kuşadasi	17232	45	37.87	27.25	22
Bilecki 17122 70 40.15 29.98 539 Malatya 17199 72 38.35 38.32 948 Bingol 17203 43 38.88 40.48 1177 Malazyirt 17780 48 93.15 42.53 1565 Bodrum 17238 63 37.72 20.28 967 Manisa 17166 73 38.62 27.43 71 Ceyhan 17960 70 37.03 35.82 30 Mardin 17275 64 37.02 40.73 1050 Ganakia 17112 66 40.15 26.42 6 Merzifon 17340 73 36.60 34.60 3 Çanakia 17084 64 39.07 38.62 953 Mug 17224 53 38.73 41.48 1320 Çoru 17054 66 41.17 27.80 83 Nigde 17250 63 37.73 34.68 1211 Çoru	Bayburt	17686	73	40.25	40.23	1584	Kütahya	17725	73	39.42	29.97	969
Bingiol 17203 43 38.88 40.48 1177 Malazgirt 17780 48 39.15 42.53 1565 Bodrum 17290 66 37.05 27.43 26 Manavgat 17954 57 36.78 31.43 38 Burdur 17238 63 37.72 30.28 967 Manisa 17186 73 36.62 27.43 71 Ceyhan 17960 70 37.03 35.82 30 Mardin 17230 64 37.02 40.33 1050 Gankale 17112 66 40.15 2.642 6 Merzifon 17083 68 40.87 35.33 755 Çankiri 17080 55 40.60 33.62 751 Mugla 17220 53 38.73 41.48 1320 Çorlu 17054 66 41.17 2.780 83 Rice 17030 73 34.62 81.19 Qoru 17084	Bilecik	17122	70	40.15	29.98	539	Malatya	17199	72	38.35	38.32	948
Bodrum 17290 66 37.05 27.43 26 Manargat 17954 57 36.78 31.43 38 Burdur 17238 63 37.72 30.28 967 Manisa 17186 73 38.62 27.43 71 Ceyhan 17960 70 37.03 35.82 30 Mardin 17275 64 37.00 40.73 1050 Cihanbeyi 17120 66 40.15 26.42 6 Mersin 17340 73 36.03 46.60 3 Coniu 17054 66 40.15 26.42 6 Mersin 17204 53 36.73 41.48 1320 Corlu 17054 66 41.17 27.80 83 Mige 17220 63 38.42 121 Qorum 17054 73 40.55 34.95 776 Ordu 17033 52 40.98 37.90 41.48 36.30 44 Din	Bingöl	17203	43	38.88	40.48	1177	Malazgirt	17780	48	39.15	42.53	1565
Burdur 17238 63 37.72 30.28 967 Manisa 17186 73 38.62 27.43 71 Ceyhan 17960 70 37.03 35.82 30 Mardin 17275 64 37.30 40.73 1050 Cihanbkyli 17800 51 38.65 32.93 968 Mersion 17083 68 40.87 35.33 755 Çankikale 17112 66 40.15 26.42 6 Mersion 17083 68 40.87 35.33 755 Çankiri 17080 55 40.60 33.62 751 Mugla 17220 68 37.97 34.68 1211 Qorum 17054 66 41.17 27.80 83 Nigde 17220 63 38.48 28.15 886 Denizii 17237 73 39.58 32.15 886 3 1211 39.58 32.15 886 Dikili 17180	Bodrum	17290	66	37.05	27.43	26	Manavgat	17954	57	36.78	31.43	38
Ceyhan 17960 70 37.03 35.82 30 Mardin 17275 64 37.30 40.73 1050 Cinanbeyli 17000 51 38.65 32.93 968 Mersin 17340 73 36.80 34.60 3 Çanakia! 17112 66 40.05 26.42 6 Merzifon 17083 68 40.87 35.33 755 Çankia! 17080 65 40.00 38.22 953 Muy 17204 53 38.73 34.48 1320 Çorlu 17054 66 41.17 27.80 83 Nitgle 17204 53 38.73 34.48 1211 Çorum 17084 73 40.55 34.95 776 Ordu 17033 52 40.98 37.90 4 Diar 17862 63 38.07 36.12 1225 Sathihi 17792 63 38.48 28.13 1111 Dirvigli	Burdur	17238	63	37.72	30.28	967	Manisa	17186	73	38.62	27.43	71
Cihanbeyli178005138.6532.93968Mersin173407336.8034.603Çanakkale171126640.1526.426Mersifon170836840.8735.33755Çankiri170805540.6033.62751Mugla172927337.2228.37646Çenigezek177686439.0738.92953Mug172045338.7341.481320Çorlu170847340.5534.95776Ordu170335240.9837.904Denizli172375537.7829.08425Polatli177287339.5832.15886Dikili171806239.0726.883Rize170407341.0340.529Dinar178626538.0730.17864Salihli177926338.4828.13111Divirgi177344839.3738.121225Samsun170307341.2886.344Dörtyol179627336.8536.2228Silir172107237.0241.95896Dursunbey177004639.5826.6751Simav177484239.0828.98809Edremit176964039.6027.0221Simav177487339.4531.531070Ferbi	Ceyhan	17960	70	37.03	35.82	30	Mardin	17275	64	37.30	40.73	1050
Çanakkale171126640.1526.426Merzíon170836840.8735.33755Çankiri170805540.6033.62751Muğla172927337.2228.37646Çemiggezek177686439.0738.92953Mug172045338.7341.481320Çorlu170546641.1727.8083Niğde172056837.9734.681211Çorum170847340.5534.95776Ordul170335240.9837.904Denizli172375537.7829.08425Polatil177287339.5832.15886Dikili171806239.0726.883Rize170407341.0340.529Dinar178626538.0730.17864Salihli177926338.4828.13111Divirgi177344839.3738.121225Samsun170307341.2836.3044Dirsurbey177004639.5826.63639Silirk172107336.3833.9315Edirem170507341.6726.5751Simay177484239.0828.98809Edremit176964039.6027.0221Sinop170267142.0235.1732Edremit </td <td>Cihanbeyli</td> <td>17800</td> <td>51</td> <td>38.65</td> <td>32.93</td> <td>968</td> <td>Mersin</td> <td>17340</td> <td>73</td> <td>36.80</td> <td>34.60</td> <td>3</td>	Cihanbeyli	17800	51	38.65	32.93	968	Mersin	17340	73	36.80	34.60	3
Cankiri170805540.6033.62751Muğla172927337.2228.37646Çerniggezek177686439.0738.92953Muş172045338.7341.481320Çorlu170546641.1727.8083Niğde172506837.9734.681211Çorum170847340.5534.95776Ordu170335240.9837.904Denizli172375537.7829.08425Polatii177287339.5832.15886Dikili171806538.0730.17864Salihli177926338.4828.13111Divrigi177344839.3738.121225Samsun170307341.2836.3044Dirylol17627336.8536.2228Silirk172107237.9241.95896Dursunbey177004639.5828.63639Silirke177307336.3833.9315Ediren176964039.6027.0221Sinop170267142.0235.1732Elazigi172017238.6739.23990Sivas170907339.4531.531070Geatartep172667340.5230.301000Şie176106341.1829.3783Gi	Çanakkale	17112	66	40.15	26.42	6	Merzifon	17083	68	40.87	35.33	755
Çenişgezek177686439.0738.92953Muş y172045338.7341.481320Çorlu170546641.1727.8083Niğde172506837.9734.681211Çorum170847340.5534.95776Ordu170335240.9837.904Denizli172375537.7829.08425Polatli177287339.5832.15886Dikili171806239.0726.883Rize170407341.0340.529Dinar178626538.0730.17864Salihli177926338.4828.13111Divrigi177344839.3738.121225Samsun170307341.2836.3044Dörtyol179627336.8536.2228Siirt172107237.9241.95896Dursunbey177004639.5828.63639Siirfke173307336.3833.9315Edime170507341.6726.5751Simav177484239.0828.98809Edremit176964039.6027.0221Sinop170267142.0235.1732Ereğli172485237.5034.051044Sivrihisar177267339.4531.531070F	Çankiri	17080	55	40.60	33.62	751	Muğla	17292	73	37.22	28.37	646
Grid 17054 66 41.17 27.80 83 Nige 17250 68 37.97 34.68 1211 Çorum 17084 73 40.55 34.95 776 Ordu 17033 52 40.98 37.90 4 Denizli 17237 55 37.78 29.08 425 Polatli 17728 73 39.58 32.15 886 Dikili 17180 62 39.07 26.88 3 Rize 17040 73 41.03 40.52 9 Dinar 17862 65 38.07 30.17 864 Salihli 17792 63 38.48 28.13 111 Divigi 17784 48 39.37 38.12 1225 Samu 17030 73 41.28 36.30 44 Diryol 17962 73 36.85 36.22 28 Silifk 17210 72 37.92 41.95 896 Dursunbey 177	Çemişqezek	17768	64	39.07	38.92	953	Muş	17204	53	38.73	41.48	1320
Gorum170847340.5534.95776Oru170335240.9837.904Denizli172375537.7829.08425Polatli177287339.5832.15886Dikili171806239.0726.883Rize170407341.0340.529Dinar178626538.0730.17864Salihli177926338.4828.13111Divriĝi177344839.3738.121225Samsun170307341.2836.3044Dirtyol179627336.8536.2228Siirt173107237.9241.95896Dursunbey177004639.5828.63639Silifke173307336.3833.9315Ediren176964039.6027.0221Sinop170267142.0235.1732Elaziğ172017238.6739.23990Sivas170907339.7537.021285Ereğli172485237.5034.051044Sivrihisar177267339.4531.531070Fethiye172966436.6229.123Şanliurfa172076637.1338.77549Gaziantep172616437.0737.38855Şebinkarahisar178224240.3038.421300	Corlu	17054	66	41.17	27.80	83	Niğde	17250	68	37.97	34.68	1211
Denizli 17237 55 37.78 29.08 425 Polatli 17728 73 39.58 32.15 886 Dikili 17180 62 39.07 26.88 3 Rize 17040 73 41.03 40.52 9 Dinar 17862 65 38.07 30.17 864 Salihli 17792 63 38.48 28.13 111 Divrigi 17734 48 39.37 38.12 1225 Samsun 17030 73 41.28 36.30 44 Dörtyol 17962 73 36.85 36.22 28 Siirt 17210 72 37.92 41.95 896 Dursunbey 17700 46 39.58 28.63 639 Siirk 17210 72 37.72 21.95 896 Edremit 17050 73 41.67 26.57 51 Simop 17026 71 42.02 35.17 32 Eraeğli	Corum	17084	73	40.55	34.95	776	Ordu	17033	52	40.98	37.90	4
Dikili 17180 62 39.07 26.88 3 Rize 17040 73 41.03 40.52 9 Dinar 17862 65 38.07 30.17 864 Salihli 17792 63 38.48 28.13 111 Divriji 17734 48 39.37 38.12 1225 Samsun 17030 73 41.28 36.30 44 Dörtyol 17962 73 36.85 36.22 28 Siirt 17210 72 37.92 41.95 896 Dursunbey 17700 46 39.58 28.63 639 Siiffke 17330 73 36.38 33.93 15 Edirme 17050 73 41.67 26.57 51 Simav 17748 42 39.08 28.98 809 Edernit 17696 40 39.60 27.02 21 Sinop 17026 71 42.02 35.17 32 Elaziğ 17201 72 38.67 39.23 990 Sivas 17090 73 <td< td=""><td>Denizli</td><td>17237</td><td>55</td><td>37.78</td><td>29.08</td><td>425</td><td>Polatli</td><td>17728</td><td>73</td><td>39.58</td><td>32.15</td><td>886</td></td<>	Denizli	17237	55	37.78	29.08	425	Polatli	17728	73	39.58	32.15	886
Dinar 17862 65 38.07 30.17 864 Salihli 17792 63 38.48 28.13 111 Divriji 17734 48 39.37 38.12 1225 Samsun 17030 73 41.28 36.30 44 Dörtyol 17962 73 36.85 36.22 28 Siirt 17210 72 37.92 41.95 896 Dursunbey 17700 46 39.58 28.63 639 Silifke 17330 73 36.38 33.93 15 Edirme 17050 73 41.67 26.57 51 Simav 17748 42 39.08 28.98 809 Edremit 17696 40 39.60 27.02 21 Sinop 17026 71 42.02 35.17 32 Elaziğ 17201 72 38.67 39.23 990 Sivas 17090 73 39.45 31.53 1070 Fethige 17266 64 36.62 29.12 3 Şanliurfa 17270 66	Dikili	17180	62	39.07	26.88	3	Rize	17040	73	41.03	40.52	9
Divriği177344839.3738.121225Samsun170307341.2836.3044Dörtyol179627336.8536.2228Siirt172107237.9241.95896Dursunbey177004639.5828.63639Silifke173307336.3833.9315Edirne170507341.6726.5751Simav177484239.0828.98809Edremit176664039.6027.0221Sinop170267142.0235.1732Elaziğ172117238.6739.23990Sivas170907339.4531.531070Fethiye172666436.6229.123Şanliurfa172706637.1338.77549Gaziantep172616437.0737.38855Şebinkarahisar176824240.3038.421300Geyve176627340.5230.301000Şile176106341.1829.3783Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada17106540.2025.9072Tokat170867040.3036.57608Gömen176745340.1027.6537Tosya176505141.0234.03870 <t< td=""><td>Dinar</td><td>17862</td><td>65</td><td>38.07</td><td>30.17</td><td>864</td><td>Salihli</td><td>17792</td><td>63</td><td>38.48</td><td>28.13</td><td>111</td></t<>	Dinar	17862	65	38.07	30.17	864	Salihli	17792	63	38.48	28.13	111
Dörtyol179627336.8536.2228Siirt172107237.9241.95896Dursunbey177004639.5828.63639Silifke173307336.3833.9315Edire170507341.6726.5751Simav177484239.0828.98809Edremit176964039.6027.0221Sinop170267142.0235.1732Elazigi172017238.6739.23990Sivas170907339.7537.021285Eregli172485237.5034.051044Sivrihisar177267339.4531.531070Fethiye172966436.6229.123Şanliurfa177206637.1338.77549Gaziantep172616437.0737.38855Şebinkarahisar176824240.3038.421300Geyve176627340.5230.301000Şile176106341.1829.3783Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada171106540.2025.9072Tokat170867040.3036.57608Gönen176745340.4739.471552Uşak171887338.6829.40919	Divriği	17734	48	39.37	38.12	1225	Samsun	17030	73	41.28	36.30	44
Dursurbey177004639.5828.63639Silifke173007336.3833.9315Edirne170507341.6726.5751Simav177484239.0828.98809Edremit176964039.6027.0221Sinop170267142.0235.1732Elaziĝ172017238.6739.23990Sivas170907339.7537.021285Ereĝli172485237.5034.051044Sivrihisar177267339.4531.531070Fethiye172966436.6229.123Şahlurfa172706637.1338.77549Gaziantep176627340.5230.301000Şile176106341.1829.3783Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada171106540.2025.9072Tokat170376541.0039.7230Gümüşhane172884536.9832.471552Uşak171887338.6829.40919Hakiari172855237.5843.731728Van171725738.5043.381661Hinis177406539.3741.701715Yalova176604640.6529.274 <t< td=""><td>Dörtyol</td><td>17962</td><td>73</td><td>36.85</td><td>36.22</td><td>28</td><td>Siirt</td><td>17210</td><td>72</td><td>37.92</td><td>41.95</td><td>896</td></t<>	Dörtyol	17962	73	36.85	36.22	28	Siirt	17210	72	37.92	41.95	896
Edirne 17050 73 41.67 26.57 51 Simav 17748 42 39.08 28.98 809 Edremit 17696 40 39.60 27.02 21 Sinop 17026 71 42.02 35.17 32 Elaziğ 17201 72 38.67 39.23 990 Sivas 17090 73 39.75 37.02 1285 Ereğli 17248 52 37.50 34.05 1044 Sivrihisar 17726 73 39.45 31.53 1070 Fethiye 17296 64 36.62 29.12 3 Şanliurfa 17270 66 37.13 38.77 549 Gaziantep 17662 73 40.52 30.30 1000 Şile 17610 63 41.18 29.37 83 Giresun 17034 73 40.92 38.40 37 Tefenni 17892 49 37.32 29.77 1142 Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70	Dursunbev	17700	46	39.58	28.63	639	Silifke	17330	73	36.38	33.93	15
Edremit 17696 40 39.60 27.02 21 Sinop 17026 71 42.02 35.17 32 Elaziğ 17201 72 38.67 39.23 990 Sivas 17090 73 39.75 37.02 1285 Ereğli 17248 52 37.50 34.05 1044 Sivris 17726 73 39.45 31.53 1070 Fethiye 17296 64 36.62 29.12 3 Şanliurfa 17270 66 37.13 38.77 549 Gaziantep 17662 73 40.52 30.30 1000 Şile 17610 63 41.18 29.37 83 Giresun 17034 73 40.92 38.40 37 Tefenni 17892 49 37.32 29.77 1142 Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70 40.30 36.57 608 Gönen 17674 53 40.10 27.65 37 Tosya 17650 51	Edirne	17050	73	41.67	26.57	51	Simav	17748	42	39.08	28.98	809
Elaziğ 17201 72 38.67 39.23 990 Sivas 17090 73 39.75 37.02 1285 Ereğli 17248 52 37.50 34.05 1044 Sivrihisar 17726 73 39.45 31.53 1070 Fethiye 17296 64 36.62 29.12 3 Şanliurfa 17270 66 37.13 38.77 549 Gaziantep 17261 64 37.07 37.38 855 Şebinkarahisar 17682 42 40.30 38.42 1300 Geyve 17662 73 40.52 30.30 1000 Şile 17610 63 41.18 29.37 83 Giresun 17034 73 40.92 38.40 37 Tefenni 17892 49 37.32 29.77 1142 Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70 40.30 36.57 608 Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037<	Edremit	17696	40	39.60	27.02	21	Sinop	17026	71	42.02	35.17	32
Ereğli172485237.5034.051044Sivrihisar177267339.4531.531070Fethiye172966436.6229.123Şanliurfa172706637.1338.77549Gaziantep172616437.0737.38855Şebinkarahisar176824240.3038.421300Geyve176627340.5230.301000Şile176106341.1829.3783Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada171106540.2025.9072Tokat170867040.3036.57608Gönen176745340.1027.6537Tosya176505141.0234.03870Gümüşhane170884540.4739.471219Trabzon170376541.0039.7230Hadim179284536.9832.471552Uşak171887338.6829.40919Hakkari172855237.5843.731728Van171725738.5043.381661Hinis177406539.3741.701715Yalova176604640.6529.274Hopa170424241.4041.4333Yozgat171404939.8234.801298<	Elaziă	17201	72	38.67	39.23	990	Sivas	17090	73	39.75	37.02	1285
Fethiye172966436.6229.123Şanliurfa172706637.1338.77549Gaziantep172616437.0737.38855Şebinkarahisar176824240.3038.421300Geyve176627340.5230.301000Şile176106341.1829.3783Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada171106540.2025.9072Tokat170867040.3036.57608Gönen176745340.1027.6537Tosya176505141.0234.03870Gümüşhane170884540.4739.471219Trabzon170376541.0039.7230Hadim179284536.9832.471552Uşak171887338.6829.40919Hakkari172855237.5843.731728Van171725738.5043.381661Hinis177406539.3741.701715Yalova176604640.6529.274Hopa170424241.4041.4333Yozgat171404939.8234.801298Isparta172407237.7730.55997Zile176814340.3035.75700 <tr< td=""><td>Ereăli</td><td>17248</td><td>52</td><td>37.50</td><td>34.05</td><td>1044</td><td>Sivrihisar</td><td>17726</td><td>73</td><td>39.45</td><td>31.53</td><td>1070</td></tr<>	Ereăli	17248	52	37.50	34.05	1044	Sivrihisar	17726	73	39.45	31.53	1070
Gaziantep 17261 64 37.07 37.38 855 Şebinkarahisar 17682 42 40.30 38.42 1300 Geyve 17662 73 40.52 30.30 1000 Şile 17610 63 41.18 29.37 83 Giresun 17034 73 40.92 38.40 37 Tefenni 17892 49 37.32 29.77 1142 Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70 40.30 36.57 608 Gönen 17674 53 40.10 27.65 37 Tosya 17650 51 41.02 34.03 870 Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037 65 41.00 39.72 30 Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172	Fethive	17296	64	36.62	29.12	3	Sanliurfa	17270	66	37.13	38.77	549
Geyve 17662 73 40.52 30.30 1000 Şile 17610 63 41.18 29.37 83 Giresun 17034 73 40.92 38.40 37 Tefenni 17892 49 37.32 29.77 1142 Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70 40.30 36.57 608 Gönen 17674 53 40.10 27.65 37 Tosya 17650 51 41.02 34.03 870 Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037 65 41.00 39.72 30 Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46	Gaziantep	17261	64	37.07	37.38	855	Sebinkarahisar	17682	42	40.30	38.42	1300
Giresun170347340.9238.4037Tefenni178924937.3229.771142Gökçeada171106540.2025.9072Tokat170867040.3036.57608Gönen176745340.1027.6537Tosya176505141.0234.03870Gümüşhane170884540.4739.471219Trabzon170376541.0039.7230Hadim179284536.9832.471552Uşak171887338.6829.40919Hakkari172855237.5843.731728Van171725738.5043.381661Hinis177406539.3741.701715Yalova176604640.6529.274Hopa170424241.4041.4333Yozgat171404939.8234.801298Isparta172407237.7730.55997Zile176814340.3035.75700Inebolu170246041.9833.7764Zonouldak170227241.4531.80137	Gevve	17662	73	40.52	30.30	1000	Sile	17610	63	41.18	29.37	83
Gökçeada 17110 65 40.20 25.90 72 Tokat 17086 70 40.30 36.57 608 Gönen 17674 53 40.10 27.65 37 Tosya 17650 51 41.02 34.03 870 Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037 65 41.00 39.72 30 Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46 40.65 29.27 4 Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 <	Giresun	17034	73	40.92	38.40	37	Tefenni	17892	49	37.32	29.77	1142
Gönen 17674 53 40.10 27.65 37 Tosya 17650 51 41.02 34.03 870 Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037 65 41.00 39.72 30 Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46 40.65 29.27 4 Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonouldak 17022 72	Gökceada	17110	65	40.20	25.90	72	Tokat	17086	70	40.30	36.57	608
Gümüşhane 17088 45 40.47 39.47 1219 Trabzon 17037 65 41.00 39.72 30 Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46 40.65 29.27 4 Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonouldak 17022 72 41.45 31.80 137	Gönen	17674	53	40.10	27.65	37	Tosva	17650	51	41.02	34.03	870
Hadim 17928 45 36.98 32.47 1552 Uşak 17188 73 38.68 29.40 919 Hakkari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46 40.65 29.27 4 Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonguldak 17022 72 41.45 31.80 137	Gümüshane	17088	45	40.47	39.47	1219	Trabzon	17037	65	41.00	39.72	30
Hackari 17285 52 37.58 43.73 1728 Van 17172 57 38.50 43.38 1661 Hinis 17740 65 39.37 41.70 1715 Yalova 17660 46 40.65 29.27 4 Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonguldak 17022 72 41.45 31.80 137	Hadim	17928	45	36.98	32.47	1552	Usak	17188	73	38.68	29.40	919
Hinkan H720 B1 B1 H720 H7200 H7200 H7200 H7200 H7200 H7200 H7200 H7200 <td>Hakkari</td> <td>17285</td> <td>52</td> <td>37 58</td> <td>43 73</td> <td>1728</td> <td>Van</td> <td>17172</td> <td>57</td> <td>38 50</td> <td>43 38</td> <td>1661</td>	Hakkari	17285	52	37 58	43 73	1728	Van	17172	57	38 50	43 38	1661
Hopa 17042 42 41.40 41.43 33 Yozgat 17140 49 39.82 34.80 1298 Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonguldak 17022 72 41.45 31.80 137	Hinis	17740	65	39.37	41.70	1715	Yalova	17660	46	40.65	29.27	4
Isparta 17240 72 37.77 30.55 997 Zile 17681 43 40.30 35.75 700 Inebolu 17024 60 41.98 33.77 64 Zonguldak 17022 72 41.45 31.80 137	Hona	17042	47	41 40	41 43	33	Yozaat	17140	49	39.82	34 80	1298
Inebolu 17024 60 41.98 33.77 64 Zonguldak 17022 72 41.45 31.80 137	Isparta	17240	72	37 77	30 55	997	7jle	17681	43	40 30	35 75	700
	Inebolu	17024	60	41.98	33.77	64	Zonguldak	17022	72	41.45	31.80	137

Table 1. Basic information of the selected stations

of the 98 stations was grouped into indiscrete clusters and the classification of extreme precipitation of Turkey based on magnitude was provided.

Results

Monthly total rainy days (*RDays*), Monthly maximum 1-day precipitation (*Rx1day*), Monthly Simple precipitation intensity index (*SDII*) and Monthly count of days when PRCP≥10 mm (*R10mm*) were calculated for each year for the 98 stations. These indices were also calculated for annual series. Annual series were evaluated for spatially classifying extreme precipitation indices (*RDays*, *Rx1Day*, *R10mm* and *SDII*) for the 98 stations based on their magnitude characteristics. Monthly data sets were assessed for describing the seasonal character of extreme precipitation.

Cluster analysis was performed with annual data sets to elucidate the distinct spatial character of precipitation extremes. Figure 1 illustrates the spatial distribution of extreme precipitation clusters. According to the dendrograms and scree plots, four classes acceptably define the spatial variability for magnitude regimes of precipitation extremes across Turkey. Cluster 1 (48 stations) corresponds spatially to Central and Eastern Anatolia, but also predominates in the more inland parts of the Black Sea region. Cluster 2 (34 stations) is concentrated mainly in the west and south of Anatolia, and especially its coastal zone. These two clusters are the most prominent classes throughout the country. Cluster 3 (13 stations) is clearly located in the Black Sea coastal zone to the north. Two stations on the northeast coast of the Black Sea region are identified with Cluster 4 (2 stations).

Box-and-whisker plots show the magnitude characteristic of the defined clusters for each index. Regarding rainy days, the highest values were detected in Cluster 4. Cluster 3, which is also located in the northern part of the country, also has a high number of rainy days. The north of Turkey experiences a longer rainy season than other regions and this precipitation regime pattern can be explained by the frequent north-eastern Atlantic-originating depressions in autumn (Sariş et al. 2010). In terms of rainy days, Cluster 1 (Central and Eastern Anatolia) has higher values than Cluster two (the west and south coastal area). The reason that Cluster 2 has the lowest values of rainy days (*RDays*) can be



Fig. 1. Spatial distribution of extreme precipitation clusters

explained by the seasonality of precipitation in this area arising from its Mediterranean climate character (Fig. 2a). For the monthly maximum of 1-day precipitation (*R1Max*), Cluster 4 again has the highest values; in fact, this cluster is characterised by the highest values of all indices. Cluster 1 has the lowest values of all indices except *RDays*. Cluster 2 and Cluster 3 show similar patterns to one another in monthly maximum of 1-day precipitation (Fig. 2b). For the other indices, simple precipitation intensity index (*SDII*) values are higher in Cluster 2 than in Cluster 3 (Fig. 2c) and for monthly count of days when precipitation exceeds 10 mm (*R10mm*), these two clusters show a resemblance (Fig. 2d).

Based on the box-and-whisker plots, the determined clusters can be characterised as;

• Cluster 1: concentrated in Central Anatolia with lowest index values of *R1Max* (34.8 mm), *SDII*

(5.3 days), *R10mm* (14.1 days) and second lowest cluster for *RDays* (117.1 days).

- Cluster 2: concentrated on western and southern coastal areas of Anatolia, namely the Aegean and Mediterranean, with high values of *SDII* (7.9 days) and *R1Max* (61.1 mm), moderate values in *R10mm* (22.9 days) and the lowest values of *RDays* (90.9 days).
- Cluster 3: concentrated in northern coastal areas of Anatolia, namely the Black Sea, with the second-highest values of *RDays* (154.8 days) and *R10mm* (26.8 days) and moderate values in *R1Max* (57.8 mm) and *SDII* (5.6 days).
- Cluster 4: localised in the north-east of the Black Sea region, with the highest values of *RDays* (181.9 days), *R1Max* (108.9 mm), *SDII* (12.4 days) and *R10mm* (67.5 days).

Figure 3 presents the intra-annual variability for each index. Figures a, b, c and d show the season-



Fig. 2. Box and Whiskers plots of annual precipitation extremes for each cluster



Fig. 3. Intra-annual variability of (a) Rainy Days (b) R1Max (c) SDII and (d) R10 indices for each cluster.

ality patterns for *RDays*, *R1Max*, *SDII* and *R10mm*, respectively. As stated before, Cluster 4 has remarkably extreme values among all indices. For *R1Max*, *SDII* and *R10mm*, all clusters exhibit clear seasonality – and, mainly, high values in autumn and winter as well. The seasonality of precipitation over Turkey is mainly dominated by the North Atlantic and Mediterranean depressions, which are influential in winter. However, the Black Sea coastal region of Turkey, and more significantly the north-east part of Turkey, are characterised by a remarkable October peak, which may be explained by prefrontal depression systems (Sariş et al. 2010).

For rainy days, Clusters 1, 2 and 3 show evident seasonality, with high rainy days values during autumn and winter (12–16 days per month) and the lowest values in summer. Cluster 4 has a distinctive character with an average of 15 rainy days per month during the year (Fig. 3a). Türkeş et al. (2008b) have studied the climatology of seasonal rainy days through Principal Component Analysis and explained spatial variability and relationships. Prior to analysis they had illustrated the spatial variability of seasonal rainy days. Although the temporal resolution of their studies is different, quite similar results were obtained.

For Cluster 2, the highest *R1max* values were seen in December. For Cluster 3 and Cluster 4 (Black Sea coastal region), the peak values of *R1max* occur in October. For Cluster 1, *R1max* values are high in the transitional seasons (Figure 3b). An earlier study by Tümertekin and Cöntürk (1958), which analysed the maximum daily precipitation totals per year for 223 stations, showed that the daily average maximum precipitation amount ranges from 20 to 150 mm. Similar results to Tümertekin's were obtained here in terms of magnitude of daily maximum precipitation. *SDII* values are highest in October for Clusters 4, 3 and 1 alike. However, Cluster 1 has very low values compared to the other clusters, and October–November values are very close to each other. Cluster 2 (Mediterranean) has a December peak in *SDII* (Fig. 3c). For *R10mm* (Fig. 3d) similar seasonality patterns were obtained for all clusters.

Figures 4 and 5 present the spatial variability of SDII and R10mm indices over Turkey, respectively. These two indices were specifically mapped since there has been no national-scale precipitation study on these indices. The simple daily precipitation index refers to rate of daily precipitation amount on wet days. The spatial variability of SDII index is greater in north-east Turkey and the Mediterranean region (from south-west to south-east along the Mediterranean coast), which corresponds to a significant proportion of annual SDII values. The SDII value is around 14 mm/day over these regions. Precipitation intensity is notable in particular areas of Turkey. The enhanced precipitation intensity over these areas refers to high amount of daily rainfall, which may lead to high overland (surface) flow and possibly flash floods based on land-use characteristics.

The *R10mm* index corresponds to the monthly count of days when daily precipitation exceeds 10 mm. In this map, annual series were evaluated. For *R10mm* indices, the north-east region still has an explicitly different pattern, along with other stations on the Black Sea coast. The yearly average value of the *R10mm* index over these areas is around 65 days. This average is around 30–40 days over the Mediterranean, where seasonality of precipitation is higher. Taking into account that the *R1Max* values concentrated between 30–120 mm for the coastal regions of Turkey, the risk of intensified surface flow might rise.

Conclusions

Daily precipitation data for 98 stations over Turkey were evaluated to elucidate the character of extreme precipitation in Turkey for selected indices at monthly and annual scale. The evaluated indices provide considerable insight into the understanding of the extreme character of precipitation; hence,

the spatiotemporal variability of extreme precipitation was determined. In order to regionalise extreme precipitation variability, Cluster Analysis was employed, and four clusters were identified for the country. The overall analysis results suggest that the coastal regions have the highest values of precipitation extremes in Turkey. For each index, the results reveal that the maximum frequency of extreme precipitation events and the highest precipitation amount occurred in the Mediterranean and Black Sea coastal regimes. The peak time of extreme precipitation events is December in the Mediterranean coastal region and October in the Black Sea coastal region. For the inland regions, both the number of extreme precipitation events and the amount of precipitation for selected percentiles are distinctly low, except rainy days.

In terms of seasonality of extreme indices, October, December and January are significant months, as peak times for extreme precipitation events, which are observed mostly in the north-east region and the Mediterranean Coast. The coastal regime regions account for a considerable amount of the detected events. The seasonal pattern of extreme precipitation indices showed that the winter conditions over Turkey, which are characterised by large-scale circulation patterns originating from the North Atlantic and Mediterranean Basin, shape the spatiotemporal variability of extreme precipitation. Coastal (Mediterranean and Black Sea) regions are distinguished, along with some transitional regions. Precipitation extremes over Turkey are significantly related to an orographically enhanced frontal rainfall pattern for the coastal regions (Saris et al. 2010; Türkeş et al. (2008a).

The obtained results for precipitation extremes have some similarities with other Mediterranean-based extreme precipitation studies (Brunetti 2004; Zhang et al. 2005; Norrant and Douguédroit 2006; Nastos and Zerefos 2007; Bartholy and Pongrácz 2007). In particular, the results of precipitation intensity and precipitation amounts over the 10-mm threshold become significant. Considering the increased frequency and intensity of hydro-meteorological hazards over Turkey (Ceylan and Kömüşçü 2007), which implies a growing risk of hazardous events such as floods and landslides; the results of precipitation analyses must be evaluated as a matter of high priority. The findings of this study sup-





Fig 4. Spatial variability of SDII index over Turkey



Fig. 5. Spatial variability of R10 index over Turkey

port the urgent need for integrated management of water resources with a wide perspective and multidisciplinary aspect. Coastal areas, and especially the Mediterranean region, are the most populated areas of the country, and are experiencing rapid land-cover changes. Therefore, this region is subject to a substantial risk of hydrometeorologically induced disasters due to the high proportion of the magnitude, frequency and duration of heavy precipitation events. Meanwhile, deforestation of upper basins for mining or hydropower investments is causing excessive overflow in the Black Sea region where flood-inducing rains are quite likely. Along with the changing pattern of precipitation amounts and timing, (precipitation intensity) the type of precipitation is also changing from snow to rain, which will restrain water availability in soil moisture and ground flow reservoirs.

To sum up, in terms of extreme precipitation variability, Turkey is facing two risks: water stress/ scarcity and flood. The annual water amount per *capita* is 1,519 m³ in Turkey (http://www.dsi.gov.tr/ toprak-ve-su-kaynaklari). According to the Falkenmark index, this value indicates that Turkey is close to experiencing water stress. Naturally, there are regional differences in terms of water availability, ranging from water surplus to water scarcity (Aydın et al. 2017). Nevertheless, water scarcity is already being felt in major cities of Turkey. In Istanbul, one such metropolis, the domestic water relies on (dammed) surface reservoirs. Since the local resources could not meet the need, water transfer between watersheds is potentially required. Multi-faceted efforts should be made to secure future water availability in Turkey. Taking into account the changes in extreme precipitation and reducing the impact of extreme precipitation, especially by protecting forest areas, are just two of the actions required in order to be able to implement an efficient water-use strategy. Reducing the amount of surface runoff and increasing direct rainfall to the soil moisture and groundwater accumulation are very important in order to provide the necessary potential for both agricultural and drinking water in the future. Enhancing knowledge about extreme precipitation events will contribute to better management of both water and the disasters resulting from changes in the climate and environment.

Acknowledgements

Precipitation data were provided from Turkey State Meteorological Service. Ozan Öztürk is thanked for cartographic assistance.

Disclosure statement

No potential conflict of interest was reported by the author.

References

- AKÇAR N, YAVUZ V, IVY-OCHS S, KUBIK PW, VARDAR M and SCHLÜCHTER C, 2007, Palaeoglacial records from Kavron Valley, NE Turkey: Field and cosmogenic exposure dating evidence. *Quaternary International* 164–165: 170–183.
- ALEXANDER LV, ZHANG X, PETERSON TC, CAE-SAR J, GLEASON B, KLEIN TANK AMG, HAY-LOCK M, COLLINS D, TREWIN B, RAHIMZADEH F, TAGIPOUR A, RUPA KUMAR K, REVADEKAR J, GRIFFITHS G, VINCENT L, STEPHENSON DB, BURN J, AGUILAR E, BRUNET M, TAY-LOR M, NEW M, ZHAI P, RUSTICUCCI M and VAZQUEZ-AGUIRRE JL, 2006, Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research* 111: D05109, DOI: https://doi:10.1029/2005JD006290
- AYDIN O, ÜNALDI ÜE, DUMAN N, ÇIÇEK İ and TÜRKOĞLU N, 2017, Türkiye'de su kıtlığının mekânsal ölçekte değerlendirilmesi. *Türk Coğrafya Dergisi* 68: 11–18 (in Turkish).
- ARNELL N, 1999, Climate Change and Global Water Resources. *Global Environmental Change* 9: 31–49.
- BARTHOLY J and PONGRÁCZ R, 2007, Regional analysis of extreme temperature and precipitation indices for from 1946 to 2001. *Global and Planetary Change* 57: 83–95.
- BOWER D, HANNAH DM and MCGREGOR GR, 2004, Techniques for assessing the climatic sensitivity of river flow regimes. *Hydrological Processes* 18: 2515–2543.
- BRUNETTI M, 2004, Changes in daily precipitation frequency and distribution in Italy over the last 120

years. Journal of Geophysical Research 109: D05102, DOI: https://doi:10.1029/2003JD004296

- CEYLAN A and KÖMÜŞÇÜ AÜ, 2007, Meteorolojik Karakterli Doğal Afetlerin Uzun Yıllar ve Mevsimsel Dağılımlari. I. Türkiye İklim Değişikliği Kongresi – Tikdek 2007. 11–13 April 2007, Istanbul Turkey, 93– 104 (in Turkish).
- ÇELIK MA, 2019, Akdeniz Kıyılarında Ekstrem Nemli Ve Kurak Mevsimlerin Dağılımı (1967–2016). Academic Platform Journal of Engineering and Science 7–1: 56–66 (in Turkish).
- FRICH P, ALEXANDER LV, DELLA-MARTA P, GLEA-SON B, HAYLOCK M, KLEIN TANK AMG and PETERSON T, 2002, Observed coherent changes in climatic extremes during 2nd half of the 20th century. *Climate Research* 19: 193–212.
- GRIFFITH DA and AMRHEIN CG, 1997, Multivariate Statistics for Geographers. Prentice-Hall: New Jersey.
- HANNAH DM, KANSAKAR SR, GERRARD AJ and REES G, 2005, Flow regimes of Himalayan rivers of Nepal: their nature and spatial patterns. *Journal of Hydrology* 308: 18–32.
- HANNAH DM, SMITH BPG, GURNELL AM and MC-GREGOR GR, 2000, An approach to hydrograph classification. *Hydrological Processes* 14: 317–338.
- HARRIS NM, GURNELL AM, HANNAH DM and PETTS GE, 2000, Classification of river regimes: A context for hydroecology. *Hydrological Processes* 14: 2831–2848.
- IYIGUN C, TÜRKEŞ M, BATMAZ İ, YOZGATLIGIL C, PURUTÇUOĞLU V, KARTAL KOÇ E and ÖZ-TÜRK MZ, 2013, Clustering current climate regions of Turkey by using a multivariate statistical method. *Theoretical and Applied Climatology* 114: 95–106. DOI: https://doi.org/10.1007/s00704-012-0823-7
- KADIOĞLU M, ÖZTÜRK N, ERDUN H and ŞEN Z, 1999, On the precipitation climatology of Turkey by Harmonic analysis. *International Journal of Climatology* 19: 1717–1728.
- KANSAKAR SR, HANNAH DM, GERRARD AJ and REES G, 2004, Spatial pattern in the precipitation regime of Nepal. *International Journal of Climatology* 24: 1645–1659.
- KLEIN TANK AMG and KÖNNEN GP, 2003, Trends in Indices of Daily Temperature and Precipitation Extremes in Europe, 1946–1999. *Journal of Climate* 16: 3665–3680.

- NASTOS PT and ZEREFOS CS, 2007, On extreme daily precipitation totals at Athens, Greece. *Advances in Geosciences* 10: 59–66.
- NASTOS PT, KAPSOMENAKIS J and DOUVIS KC, 2013, Analysis of precipitation extremes based on satellite and high-resolution gridded data set over Mediterranean basin. *Atmospheric Research*, 131: 46–59.
- NORRANT C and DOUGUÉDROIT A, 2006, Monthly and daily precipitation trends in the Mediterranean (1950–2000). *Theoretical and Applied Climatology* 83: 89–106.
- OIKONOMOU C, FLOKAS HA, HATZAKI M, ASIMA-KOPOULOS DN and GIANNAKOPOULOS C, 2008, Future changes in the occurrence of extreme precipitation events in Eastern Mediterranean, *Global NEST Journal* 10(2): 255–262.
- PARTAL T and KAHYA E, 2006, Trend analysis in Turkish precipitation data. *Hydrological Processes* 20: 2011– 2026.
- PAXIAN A, HERTIG E, SEUBERT S, VOGT G, JAC-OBEIT J and PAETH H, 2015, Presentday and future Mediterranean precipitation extremes assessed by different statistical approaches. *Climate Dynamics* 44: 845–860.
- PETERSON TC, FOLLAND C, GRUZA G, HOGG W, MOKSSIT A and PLUMMER N, 2001, Report on the activities of the Working Group on Climate Change Detection and Related Reporters 1998–2001. World Meteorological Organisation Rep. WCDMP-47, WMO-TD 1071, Geneva, Switzerland, 143.
- RAJA NB, AYDIN O, TÜRKOĞLU N and ÇIÇEK İ, 2017, Space-time kriging of precipitation variability in Turkey for the period 1976–2010. *The*oretical and Applied Climatology 129: 293–304. DOI: https://doi 10.1007/s00704-016-1788-8
- SARIŞ F, HANNAH DM and EASTWOOD WJ, 2010, Spatial variability of precipitation regimes over Turkey. *Hydrological Sciences Journal* 55(2): 234–249.
- ŞEN Z and HABIB Z 2000, Spatial analysis of monthly precipitation in Turkey. *Theoretical and Applied Climatology* 67: 81–96.
- ŞENSOY S, TÜRKOĞLU N, AKÇAKAYA A, EKICI M, DEMIRCAN M, ULUPINAR Y, ATAY H, TÜVAN A and DEMIRBAŞ H, 2013, *Trends in Turkey Climate Indices from 1960 to 2010*. In 6th Atmospheric Science Symposium – ATMOS 2013 3 – 5 Haziran 2013, İstanbul.
- TATLI H, DALFES N and MENTEŞ S, 2004, A statistical downscaling method for monthly total precipita-

tion over Turkey. *International Journal of Climatology* 24: 161–188.

- TÜMERTEKIN E and CÖNTÜRK H, 1958, Türkiye'de günlük maksimum yağışlar. *Coğrafya Enstitüsü Dergisi* 9: 115–121 (Turkish).
- TÜRKEŞ M, 1996, Spatial and temporal analysis of annual rainfall variations in Turkey. *International Journal of Climatology* 16: 1057–1076.
- TÜRKEŞ M, 1998, Influence of geopotential heights, cyclone frequency and southern oscillation on rainfall variations in Turkey. *International Journal of Climatology* 18: 649–680.
- TÜRKEŞ M, KOÇ T and SARIŞ F, 2008a, Spatiotemporal variability of precipitation total series over Turkey. *International Journal of Climatology* 29(8): 1056–1074.
- TÜRKEŞ M, KOÇ T, and SARIŞ F, 2008b, Türkiye'de yağışlı gün sayılarının klimatolojisi ve alansal ilişki desenleri, Atmosfer Bilimleri Sempozyumu IV, İstanbul, Türkiye, 25–28 Mart 2008: 500–511 (Turkish).
- ÜNAL Y, KINDAP T, KARACA M, 2003, Redefining the climate zones of Turkey using cluster analysis. *International Journal of Climatology* 23: 1045–1055.
- YARNAL B, 1992, Synoptic Climatology in Environmental Analysis: A Primer. Belhaven Press: London.

- YEŞILIRMAK E and ATATANIR L, 2016, Spatiotemporal variability of precipitation concentration in western Turkey. *Natural Hazards* 81: 687–704. DOI: https://doi 10.1007/s11069-015-2102-2
- YILMAZ AG, 2015, The effects of climate change on historical and future extreme rainfall in Antalya, Turkey. *Hydrological Sciences Journal* 60(12): 2148–2162. DOI: https://doi:10.1080/02626667.2014.945455
- ZHANG X, AGUILAR E, SENSOY S, MELKON-YAN H, TAGIYEVA U, AHMED N, KUTALADZE N, RAHIMZADEH F, TAGHIPOUR A, HAN-TOSH TH, ALBERT P, SEMAWI M, ALI MK, AL-SHABIBI MHS, AL-OULAN Z, ZATARI T, KHELET IAD, HAMOUD S, SAGIR R, DEMIR-CAN M, EKEN M, ADIGUZEL M, ALEXANDER L, PETERSON TC and WALLIS T, 2005, Trends in Middle East climate extreme indices from 1950 to 2003. Journal of Geophysical Research 110: D22104. DOI: https://doi:10.1029/2005JD006181
- TURKEY'S GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS, http://www.dsi.gov.tr/toprak-ve-su-kaynaklari

Received 4 September 2020 Accepted 2 November 2020