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

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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 Mediterranean 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; Şen 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 total rainy days, (*Rx1day*) Monthly maximum 1-day precipitation, (*SDII*) Simple precipitation intensity index, and (*R10mm*) Monthly count of days when PRCP≥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:

$$Rx1day_j = \max(RR_{ij})$$

- *SDII*, Simple precipitation intensity index:

Let *RRwj* be the daily precipitation amount on wet days, *w (RR ≥ 1mm)* 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:

$$RRij \geq 10mm$$

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

Table 1. Basic information of the selected stations

Station Name	Station Number	Data Lentgh	Latitude (N)	Longitude (E)	Altitude (m a.s.l.)	Station Name	Station Number	Data Lentgh	Latitude (N)	Longitude (E)	Altitude (m a.s.l.)
Adana	17351	73	37.00	35.33	27	Ipsala	17632	46	40.93	26.40	10
Adiyaman	17265	65	37.75	38.28	672	Iskenderun	17370	63	36.58	36.17	4
Ağri	17099	65	39.72	43.05	1632	Ispir	17666	50	40.48	41.00	1222
Akhisar	17184	66	38.92	27.85	93	Izmir	17220	65	38.43	27.17	25
Aksaray	17834	64	38.38	34.08	965	Kahramanmaraş	17255	49	37.60	36.93	572
Amasya	17085	67	40.65	35.83	412	Karaman	17932	66	37.18	33.22	1025
Anamur	17320	59	36.08	32.83	4	Kars	17098	73	40.62	43.10	1775
Ankara	17130	73	39.95	32.88	891	Kastamonu	17074	73	41.37	33.78	800
Antakya	17984	62	36.20	36.17	100	Kayseri	17196	66	38.73	35.48	1093
Ardahan	17630	65	41.12	42.72	1829	Kirklareli	17052	70	41.73	27.23	232
Artvin	17045	57	41.18	41.82	628	Kizilcahamam	17664	46	40.47	32.65	1033
Aydin	17234	72	37.85	27.85	56	Kilis	17978	71	36.72	37.12	638
Bafra	17622	50	41.57	35.92	20	Kocaeli	17066	65	40.78	29.93	76
Bandirma	17114	57	40.35	27.97	58	Kuşadasi	17232	45	37.87	27.25	22
Bayburt	17686	73	40.25	40.23	1584	Kütahya	17725	73	39.42	29.97	969
Bilecik	17122	70	40.15	29.98	539	Malatya	17199	72	38.35	38.32	948
Bingöl	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	38.62	27.43	71
Ceyhan	17960	70	37.03	35.82	30	Mardin	17275	64	37.30	40.73	1050
Cihanbeyli	17800	51	38.65	32.93	968	Mersin	17340	73	36.80	34.60	3
Çanakkale	17112	66	40.15	26.42	6	Merzifon	17083	68	40.87	35.33	755
Çankiri	17080	55	40.60	33.62	751	Muğla	17292	73	37.22	28.37	646
Çemişgezek	17768	64	39.07	38.92	953	Muş	17204	53	38.73	41.48	1320
Çorlu	17054	66	41.17	27.80	83	Niğde	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
Divriği	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
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	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	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

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

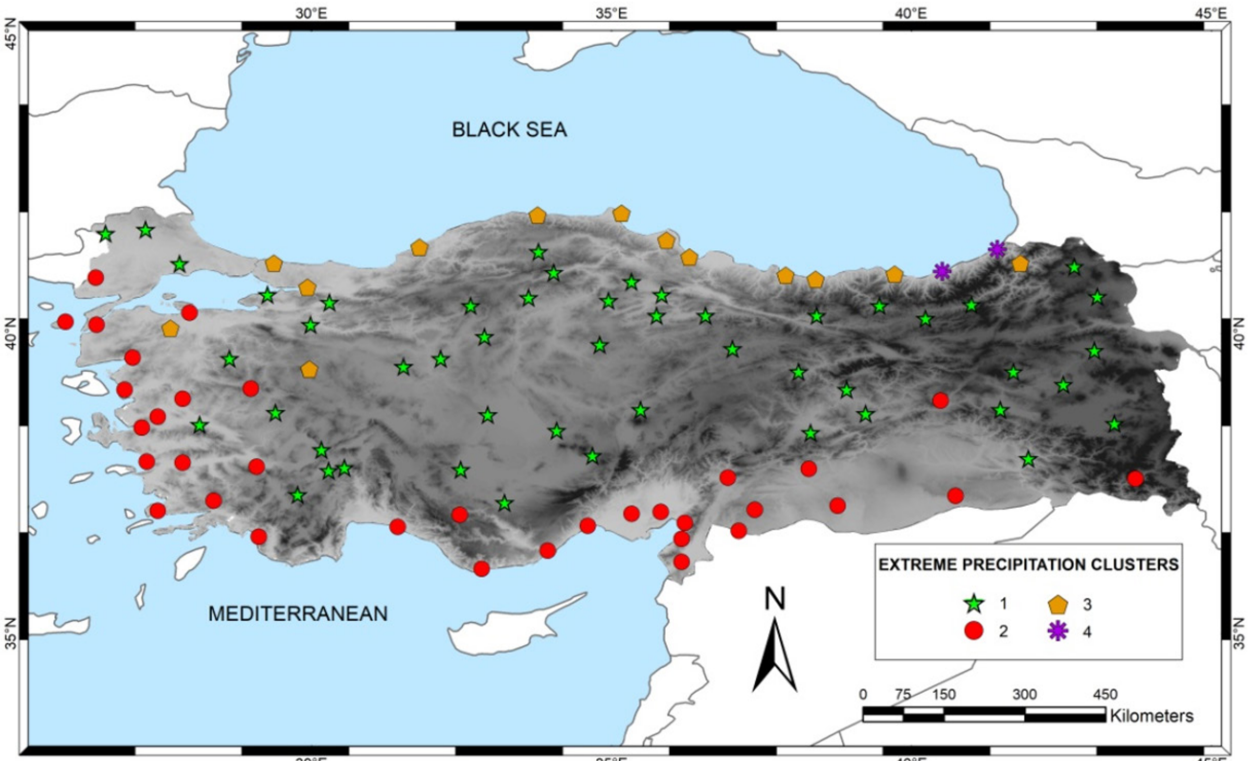

Fig. 1. Spatial distribution of extreme precipitation clusters

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-

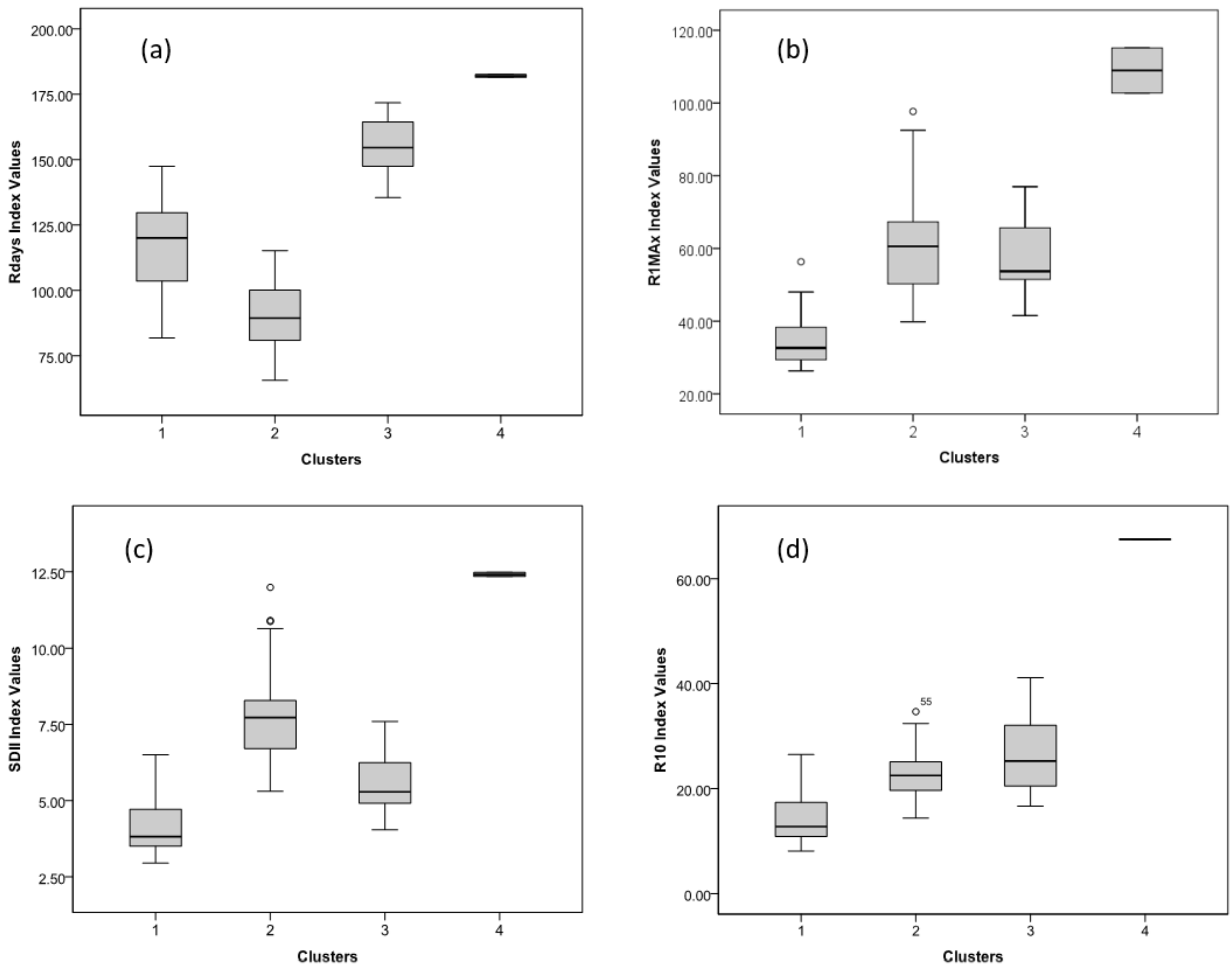

Fig. 2. Box and Whiskers plots of annual precipitation extremes for each cluster

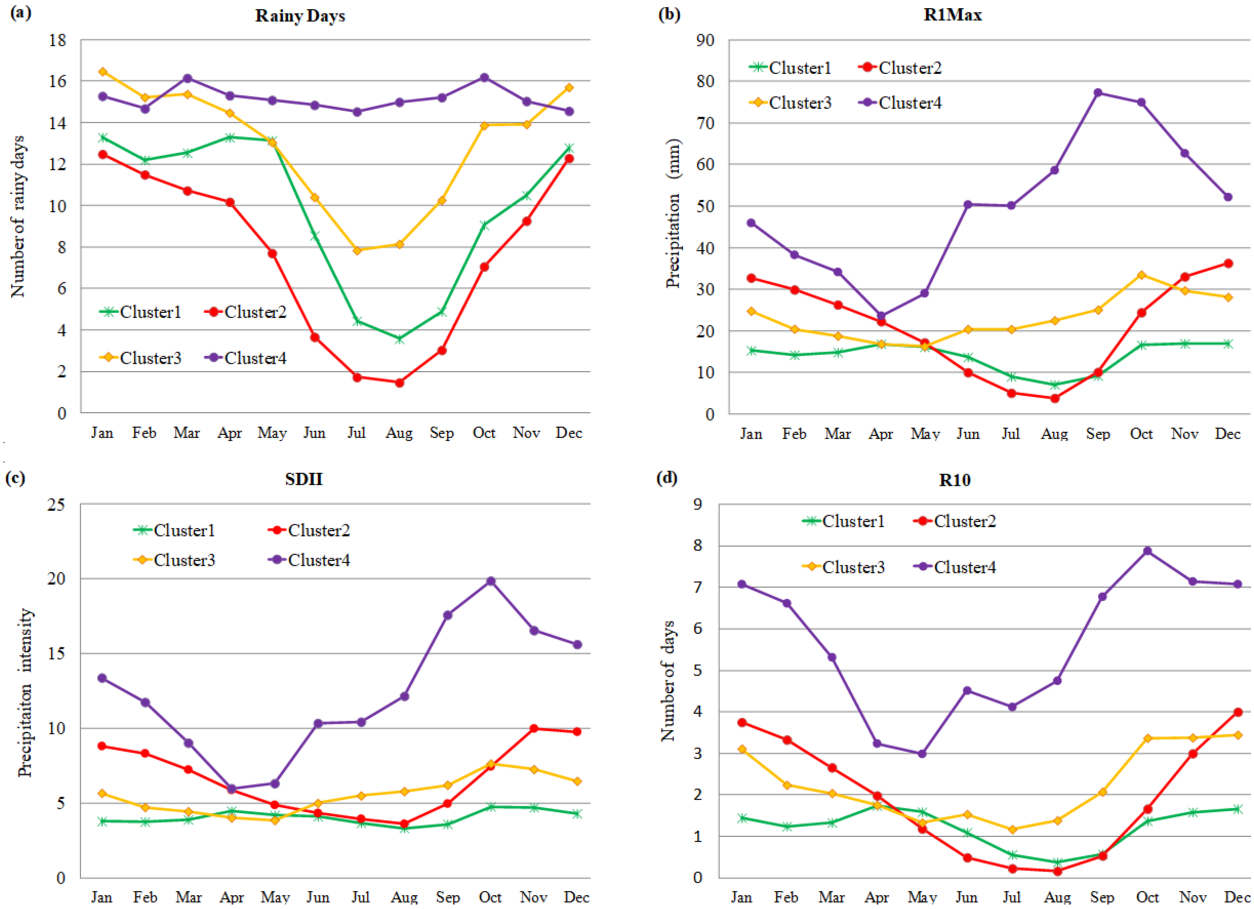

Fig. 3. Intra-annual variability of (a) Rainy Days (b) R1Max (c) SDII and (d) R10 indices for each cluster.

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-

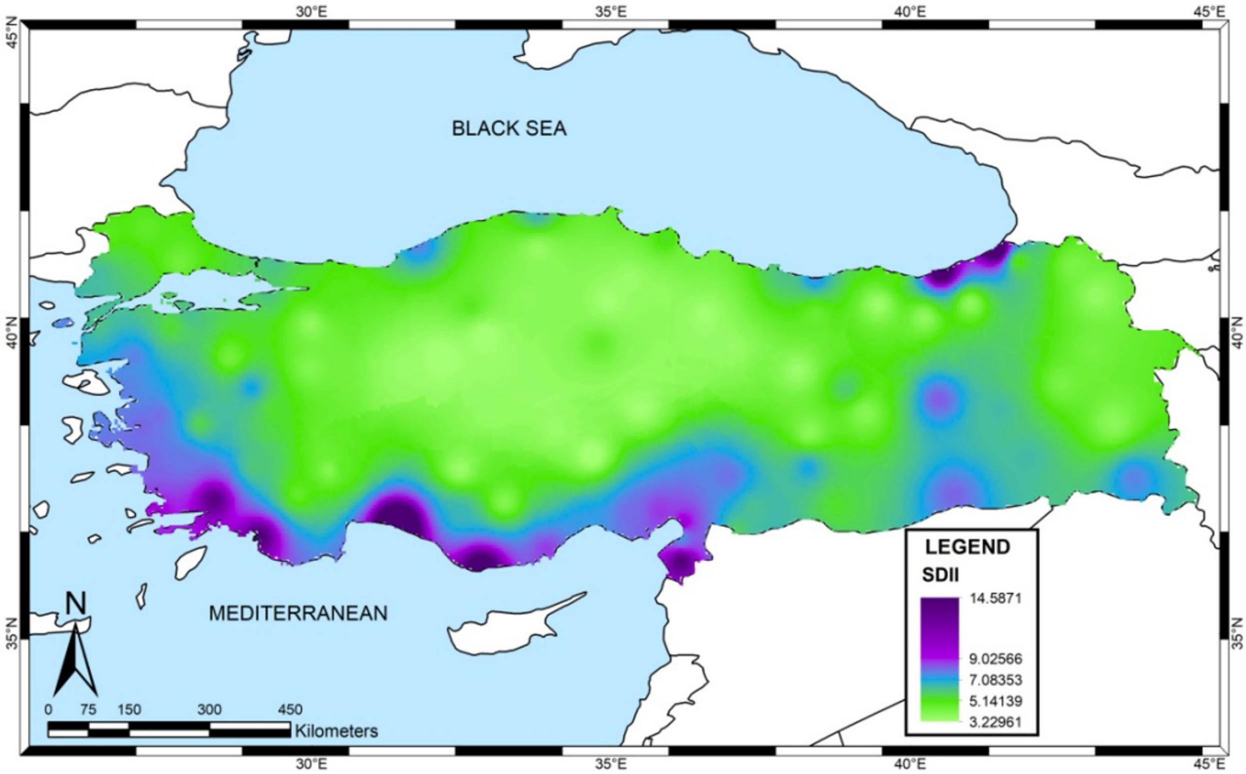

Fig 4. Spatial variability of SDII index over Turkey

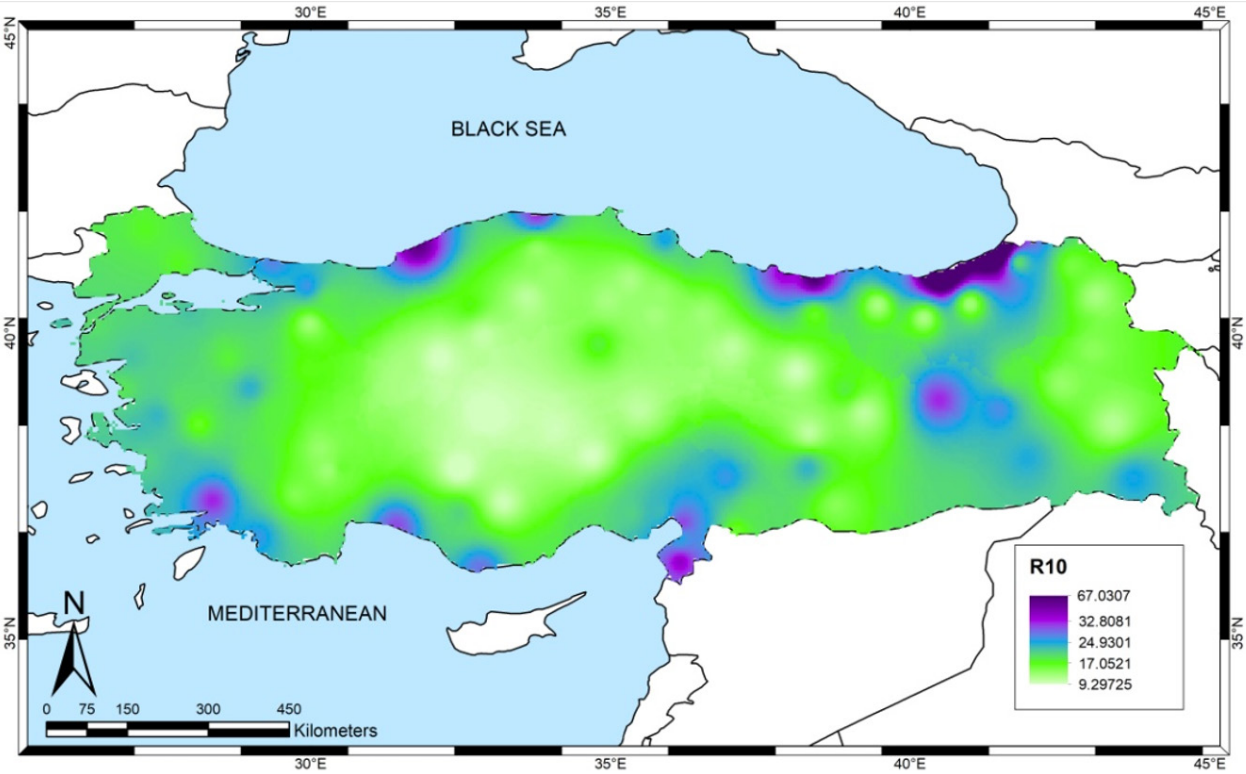

Fig. 5. Spatial variability of R10 index over Turkey

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.

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Disclosure statement

No potential conflict of interest was reported by the author.

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