Chapter 8
Turkey: Climate Variability, Extreme Temperature, and Precipitation

Barbaros Gönençgil and Zahide Acar

Abstract Climate variability and climate change have significant impacts in many areas of the world with different effects. It is generally accepted that changing climate variability and consequently changes in the intensity and frequency of extreme climatic events may have strong effects on sensitive areas. The east of the Mediterranean Basin in Turkey is one area where significant effects of climate variability may be experienced. Increases in extreme hot weather events and weak but distinct decreasing tendencies in extreme cold weather events are worth noting. Therefore, the increase in temperature, which has been rising since the early 2000s, is also combined with decreases in very cold days. In addition, the decreasing tendencies in total precipitation are accepted in many weather stations as important signals of long-term drought. The increasing trend of consecutive dry days and the decreasing trend of consecutive wet days can be considered as an indication that severe precipitation events will be more pronounced in annual total precipitation.

Keywords Climate variability · Turkey · Temperature · Precipitation · Climate indices

8.1 Introduction

Climate change is defined as trends in the direction of an increase or decrease in the average or variability of climate elements globally over long time scales. Since climate change has become an important issue, doubts about the reliability of the data used in the analysis have rightly increased. It is known that the changes and trends

B. Gönençgil (✉)
Istanbul University, Faculty of Letters, Department of Geography, İstanbul, Turkey
e-mail: barbaros@istanbul.edu.tr

Z. Acar
Canakkale Onsekiz Mart University, Faculty of Arts and Sciences, Department of Geography, Canakkale, Turkey
e-mail: zacar@comu.edu.tr

R. C. Lois-González (ed.), *Geographies of Mediterranean Europe*, Springer Geography, https://doi.org/10.1007/978-3-030-49464-3_8

of many long-term climatological time series are not only caused by changes in weather and climate.

The climate is variable in nature, and it is possible to see this variation in nature on a spatial and temporal scale. A significant portion of this variability, such as year to year or season to season, is only partially understood (Hare 1991; Smithers and Smit 1997; Thornton et al. 2014). In addition to the natural cycle of climate, climate change has strengthened due to the negative effects of human beings on the Earth's atmosphere. Nowadays, the increases in frequency and intensity of some natural disasters can be accepted as an indicator of climate change.

Today's rapidly increasing human activities lead to faster changes in the Earth's climate. The most significant parameter of the changes in climate relate to air temperatures. With the increase in frequency and intensity of extreme weather events, climate variability has increased to a greater extent.

Climate change in Turkey has long been one of the major issues related to climate studies. Turkey remains under the influence of different air masses in geographical location as winter and summer seasons. The seasonal differences due to the geographical location increase with the effect of the geographical position. Generally, Turkey is under the influence of a type of tropical airflow in summer, while it is under the influence of winter polar air in winter. The air currents which occur in Turkey are seen as the Siberian anticyclone, and as the polar front depression in winter, it develops under the influence of Azores anticyclone and under the influence of low pressure from Basra which is an extension of the Monsoon low pressure (Erinç 1996; Erol 1999; Gönençgil 2008; Koçman 1993).

Depending on the characteristics of the general atmospheric circulation, Turkey and the surrounding area are entirely dominated by tropical air masses in summer. The western and northwestern regions of the region are occupied by marine air masses (maritime tropical (mT)), while the southeast and southern regions by (continental tropic (cT)) air masses coming from the Atlantic. In summer, there are no polar air masses in the Mediterranean Basin. Because Europe is in the north of the field, it is hot in this season. Polar air masses to the north are less likely to be introduced into the Mediterranean Basin in summer. In summer, atmospheric flows are unsuitable for front and cyclone formation. According to previous studies, Turkey's total annual winter rainfall was generally increasing until the 1960s; however, since the 1970s, decreasing trends have been identified. According to previous studies conducted in the Mediterranean, Southeast Anatolia regions, and urban weather stations, significant warming trends in temperatures have been observed in more densely areas (Acar and Gönençgil 2019; Acar et al. 2018; Deniz 2016; Erlat and Türkeş 2015; Gönençgil 2019; Gönençgil and Acar Deniz 2016).

When we examine the general country distribution of Turkey's average temperature, lower temperatures latitudinally are observed in the northern parts than in the southern parts. Similarly, lower averages are seen in the inner and eastern parts where greater elevation is apparent. According to Mann-Kendall trend analysis, the increasing trend is dominant in Turkey's air temperatures (Kendall 1975; Mann 1945). These rising trends, which are particularly strong at minimum temperatures,

are quite pronounced at average temperatures. Weather stations where significant upward trends are weaker are generally seen in remote, rural stations in city centers.

8.2 Extreme Temperature Events

Many studies about extreme temperatures using different thresholds have been carried out in Turkey. The common result of these studies is that extreme temperature events are increasing and extreme cold events are decreasing (Acar and Gönençgil 2019; Erlat and Yavaşlı 2009; Şensoy et al. 2008; Ünal et al. 2012). Due to the increase in extreme climatic events, severe events such as hot/cold air waves and dry periods/extreme rainy periods are among the most studied subjects in the Mediterranean Basin. The effects of heat waves and extreme events in Greece, Balkans, and Romania in 2007 were investigated after the heat wave that caused a large number of deaths in 2003 in Western Europe and especially in France and its surroundings. Many researchers developed a set of indices for climate parameters in order to objectively evaluate extreme climate events (Alexander et al. 2006; Fernández-Montes and Rodrigo 2012; Frich et al. 2002; Klein Tank and Können 2003; Luterbacher et al. 2004). This index is made by utilizing the array of considerations related to spatial and temporal distributions of extreme temperatures in Turkey.

The study area covers the region bounded by 26°E–45°E longitude and 36°N–42°N latitude, which includes Turkey. Daily maximum and minimum temperature and precipitation records were provided for 158 weather stations by the Turkish State Meteorological Service for the period 1964–2014. According to the Mann-Kendall test, a statistically significant upward trend in average temperature was observed in almost all of these weather stations in Turkey (Fig. 8.1).

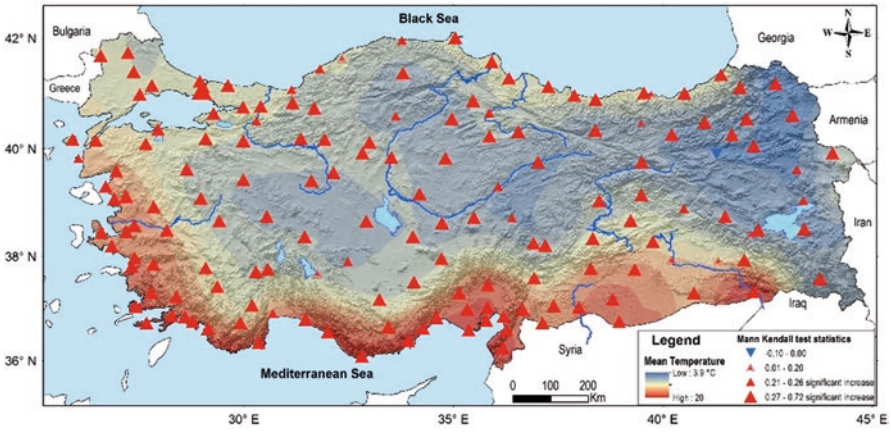

Fig. 8.1 The spatial distribution precipitation and trend change of total precipitation based on Mann-Kendall rank test

Temperature indices used in the study can be evaluated in two groups. The first group is to determine the frequency (Max > 25, Min > 20, Min < 0 °C, Max < 0 °C) of indices of the specified threshold. The second group is the indices used to calculate temperature changes (extreme temperature range). These indices, where the effects of climate change can be observed, and the indices of daily temperatures have been calculated. In this study, the indices applied for temperatures are listed in Table 8.1.

8.2.1 Summer Days

The largest number of summer days is on the southeastern and southern coast of Turkey. There was an average of 85–90 days of summer in these areas during the 1964–2014 periods. This number falls in the high plateau and mountainous area in Turkey's northeast to 55 days (Fig. 8.2). The number of summer day's index was the highest in 1998, 2001, 2003, 2006, and 2008. The lowest summer day's indices were 1967, 1968 1976, 1983, and 1984. Overall, the average number of summer days decreased in the 1966–2014 periods from south to north. The highest number of summer days could be observed in the Southeastern Anatolia Region and at weather stations in southwest Turkey, while the lowest number of summer days is recorded in Anatolia.

Table 8.1 Definitions of the temperature indices used in this study

Index	Descriptive name	Definition
SU	Summer days	Annual count of days when TX (daily maximum temperature) > 25 °C
TN	Tropical night	Annual count of days when TN (daily minimum temperature) > 20 °C
FD	Frosty days	Annual count of days when TN (daily minimum temperature) < 0 °C
ID	Icy day	Annual count of days when TX (daily maximum temperature) < 0 °C
DTR	Daily temperature range	Monthly mean difference between TX and TN
R99p	Extreme humid days	Annual total PRCP when RR > 99th percentile
R95p	Very wet days	Annual total PRCP when RR > 95th percentile
SDII	Simple daily intensity index	Total rainfall = total rain day per year
CDD	Consecutive dry days	Maximum number of consecutive days with daily precipitation <1 mm
CWD	Consecutive wet days	Maximum number of consecutive days with daily precipitation ≥1 mm

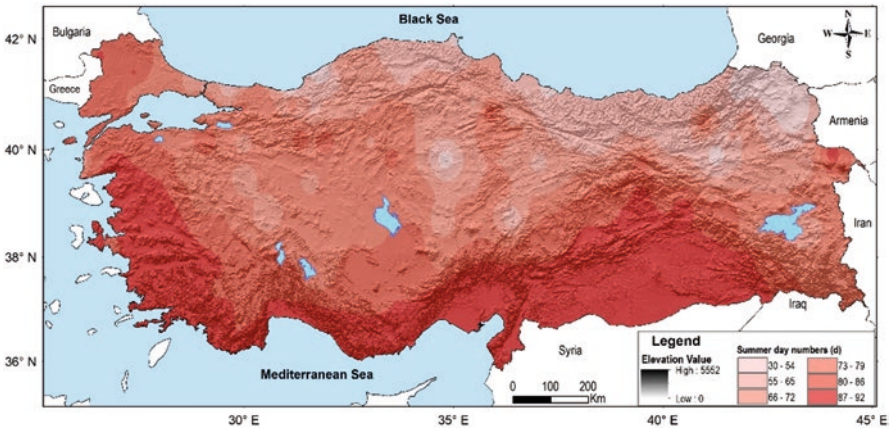

Fig. 8.2 Spatial distribution of summer day numbers

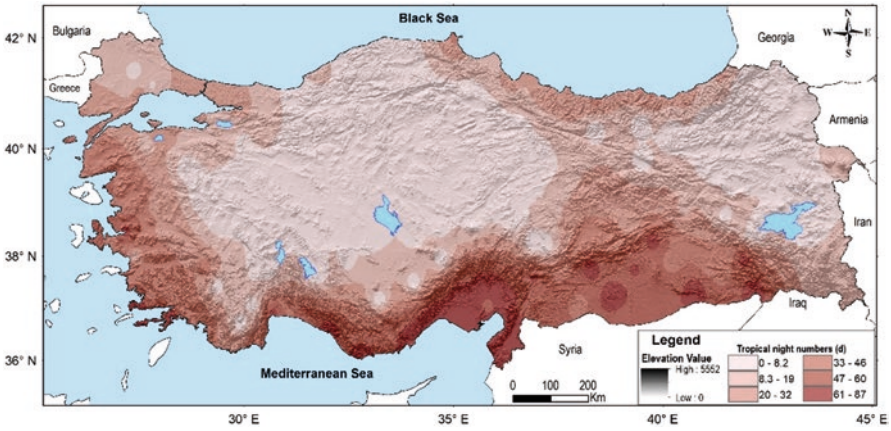

Fig. 8.3 Spatial distribution of tropical night numbers

8.2.2 Tropical Nights

The average numbers of tropical night decreased for the 1964–2014 period, from south to north (Fig. 8.3). The highest number of tropical night can be observed around the Gulf of Iskenderun, while the lowest values are observed in Turkey's northeast with the Western Black Sea. Summer 2010 is the period with the greatest extreme temperature anomalies. The fewest tropical nights were experienced in 1968, 1969, 1976, 1982, and 1984. While inter-year changes do occur, the highest numbers of tropical nights have all been observed in the last 20 years.

8.2.3 Frosty Days

The number of frosty days increases toward the east to the west of Turkey. The highest number of frosty days is recorded in Eastern Anatolia where the number of frosty days reaches the highest values, especially in the north of Van (Fig. 8.4). The shores of the Mediterranean and Aegean Sea and the surrounding area of Istanbul are the areas with the lowest number of frosty days. Maritime effect and elevation are the most important factors in the distribution of frosty days. The warming effect of the sea can be seen throughout the coastal area. There is a significant spatial change in the number of frosty days due to the effect of topography from the coast to the inland areas. The maritime effect of the Aegean coastline reaches the inner parts of the sea with the effect of topography.

8.2.4 Icy Days

Generally there is an increase from west to east in the number of icy days. Icy locations can be mostly seen in the East Anatolia Region, especially in the northeast of Turkey. In these areas, approximately 60 days of winter are icy days (Fig. 8.5). In the 1964–2014 period, there were almost no icy days at the Mediterranean coastal belt and the Aegean coast weather stations.

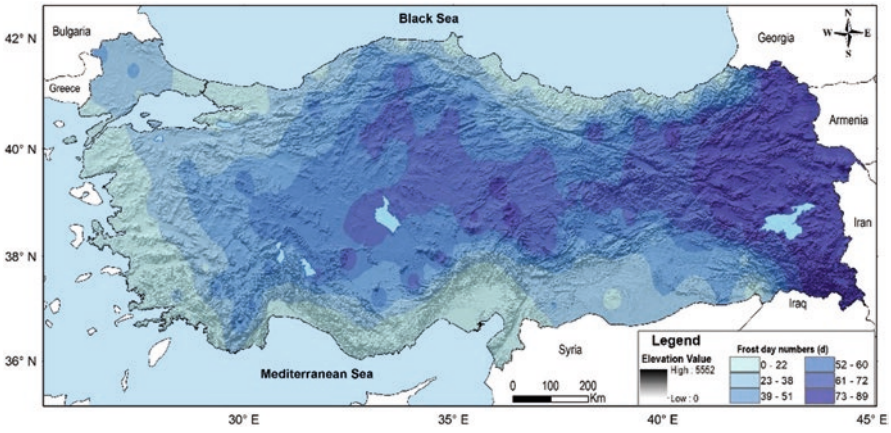

Fig. 8.4 Spatial distribution of frost day numbers

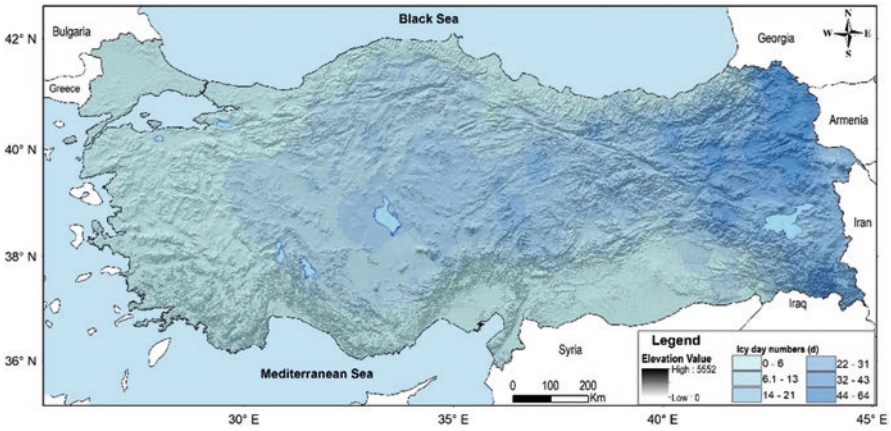

Fig. 8.5 Spatial distribution of icy day number

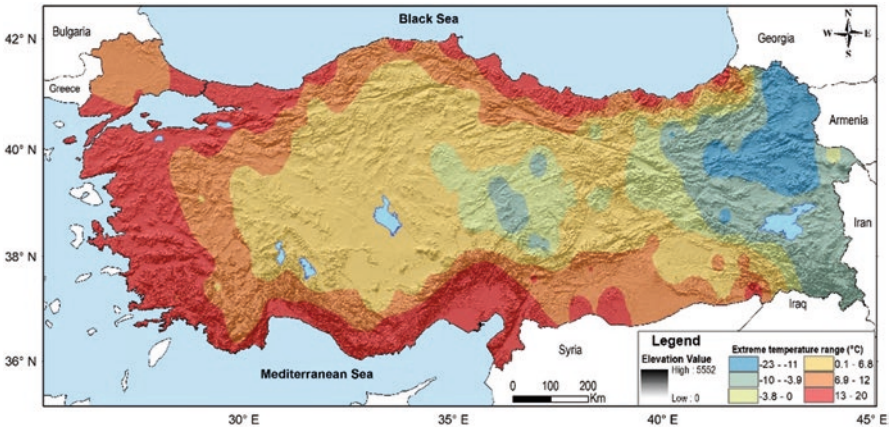

Fig. 8.6 Spatial distribution of extreme temperature range

8.2.5 Daily Temperature Range

The daily temperature range is calculated by taking the difference between the highest temperature and the lowest temperature observed in the same calendar year. According to the analysis made for winter, 1972 (2.6 days), 1992 (2.7 days), 1976 (2.9 days), 1993 (4.2 days), and 1974 (4.6 days) were the years when the daily temperature range was lowest. The daily temperature range is highest in the years 2010 (12.7 days), 1966 (12.3 days), 2013 (12.3 days), 2011 (12 days), and 1970 (11.4 days). From 1964 to 2014, the total number of winter days with extreme seasonal temperature range decreased from east to west (Fig. 8.6). The highest extreme

temperature ranges can be observed in Eastern and Southeastern Anatolia. In addition, the daily temperature range in winter is highest in the interior. The most decisive factor in this temperature index is terrestrial-marine. Extreme values are seen less in winter extreme temperatures in coastal weather stations and surrounding areas where marine effects are evident. In addition, extreme temperature differences between hot and cold values are not as high as in the eastern part of Turkey.

8.3 Extreme Rain Events

Scarcity, drought, and low total annual precipitation, in the Mediterranean region (Spain, Greece, Italy, Turkey etc.), are some of the most important climatic variables discussed by many researchers. Studies show that long-term drought events occur in the Mediterranean Basin (Bordi et al. 2001; Livada and Assimakopoulos 2007; Vicente-Serrano and Lopez-Moreno 2005). Turkey experienced drought events due to the lack of rainfall in general, especially in the period 1970–2000. Annual total precipitation decreases and increases can be observed. The decreasing tendencies are apparent in the Mediterranean and Aegean coasts, which generally have the Mediterranean precipitation regime (Fig. 8.7).

Indices used for extreme rains are described in Table 8.1. Rain indices can be evaluated in two groups. The first group is calculated to determine the percentage (P < 99th) of values exceeding the percentage limit of the index used for precipitation, to determine the frequency (P20 mm) of the index whose threshold was determined. The second group is the indices used to calculate precipitation change (consecutive dry days).

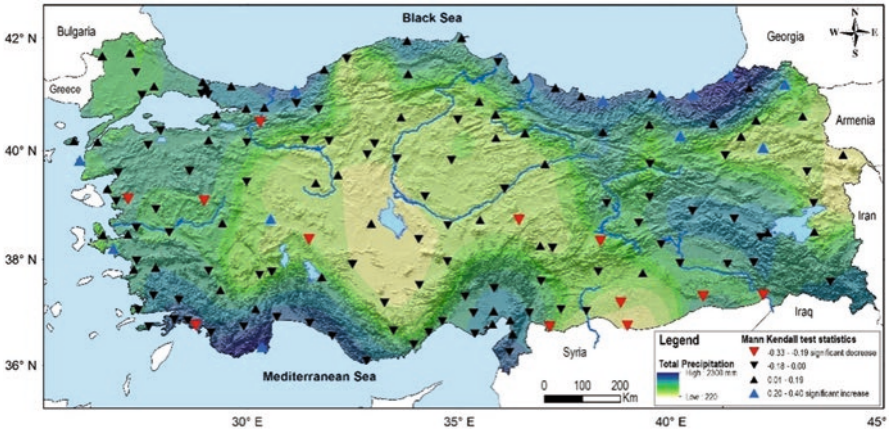

Fig. 8.7 The spatial distribution precipitation and trend change of total precipitation based on Mann-Kendall rank test

8.3.1 Extreme Humid Days

The extreme humid day index determines when seasonal rainfall is above average. The extreme humid day index in winter is similar to the humid day index. The most humid years were experienced in 1990 (4.9 days), 1969 (3.3 days), 2002 (3.1 days), 2013 (3 days), 1981 (3 days), 2004 (2.9 days), and 2010 (2.8 days). The weather stations in the Black Sea coastal zone and the Tunceli-Bitlis belt in the Menteşe region of the Aegean region, north of the Southeastern Taurus Mountains, have the highest humidity. Excessively humid days with precipitation have shown a downward trend since the 1970s. 1973–1974 correspond to a statistically significant dry period. 1989 and 2014 were the years with the least number of extreme humid days, while 1990 was the year with the highest number of humid days. In Southeastern Anatolia, the Mediterranean, and Aegean regions, the number of extreme humid days is lower than the average. These areas are influenced by the Mediterranean precipitation regime. The area of influence of typical summer drought shows a significant distribution in the distribution maps of extreme humid and humid days. The highest summer extreme humid days are observed in Eastern Anatolia and Central Anatolia Regions (Fig. 8.8).

8.3.2 Very Wet Days

It can be said that days with 20 mm and above of precipitation are often in areas where the Mediterranean precipitation regime is seen. Very wet days in winter are generally similar to extreme humid day index. Rainfall of 20 mm or more is observed at the weather stations in the coastal Aegean region, the Menteşe region, the Mediterranean coastal zone, the Eastern Black Sea region (Rize and Hopa), and the

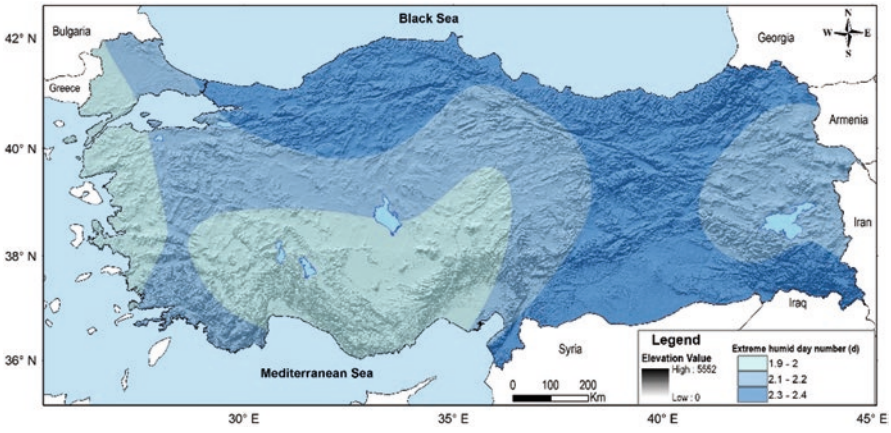

Fig. 8.8 Spatial distribution of extreme humid day numbers

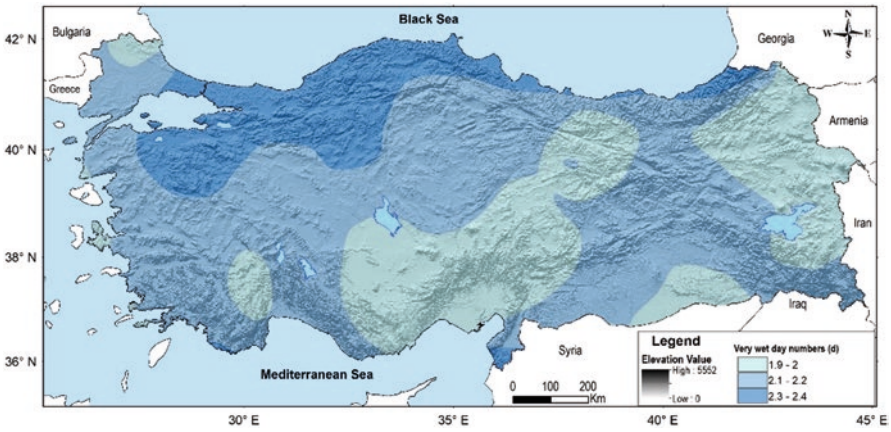

Fig. 8.9 Spatial distribution of very wet day numbers

northern part of the Southeastern Taurus. The years 1967, 1969, 1978, 1981, 2002, 2004, and 2010 were the years when the most severe rainfall occurred and 1972, 1973, 1989, 2001, 2007, and 2014 the least. The number of days of rainfall of 20 mm or more shows a weak upward trend in most of the weather stations in the Black Sea Region (except Hopa, Rize, and İnebolu) and Central Anatolia. In most of the areas dominated by the Mediterranean precipitation regime, the trend toward a decrease in very wet days is clear (Fig. 8.9).

8.3.3 Simple Precipitation Intensity Index

The precipitation intensity index gives the average precipitation on rainy days. The highest values for the distribution of winter precipitation intensity are observed in the Mediterranean coastal belt; the highest rainfall in the area in the west of Turkey can be seen in Rize and Hope weather stations (Fig. 8.10). Simple precipitation intensity in Turkey ranges from 4 to 24 mm. Weather stations in the Mediterranean coastal zone show significant regionality with a simple precipitation intensity index. Since the annual rainfall rates for the inner parts are also low, the rainfall intensity in these areas varies between 4 and 7 mm. The reason for the low simple precipitation intensity index may be that precipitation does not fall in the form of rainfall in northeast and eastern part of Turkey. In recent years, simple precipitation intensity index includes a trend toward increasing throughout Turkey. After the significant dry stretch from 1971 to 1974, a significant increase in precipitation intensity series can be seen. Although there was an increase, the precipitation index has started to show values above the average since 2010.

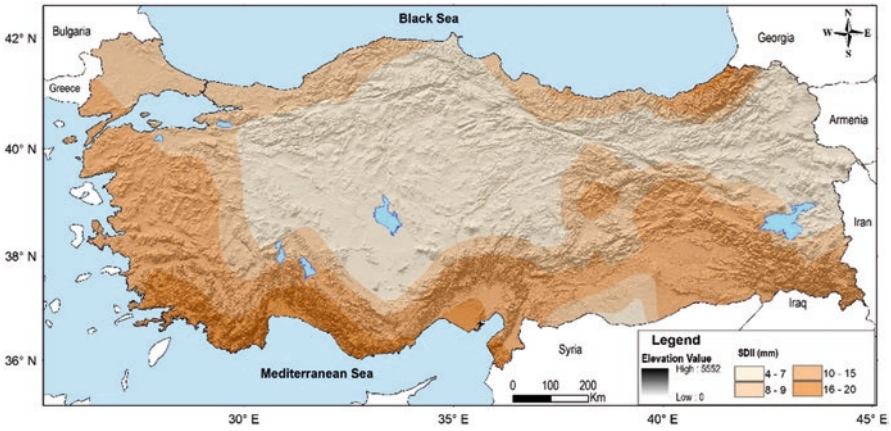

Fig. 8.10 Spatial distribution of simple precipitation intensity index

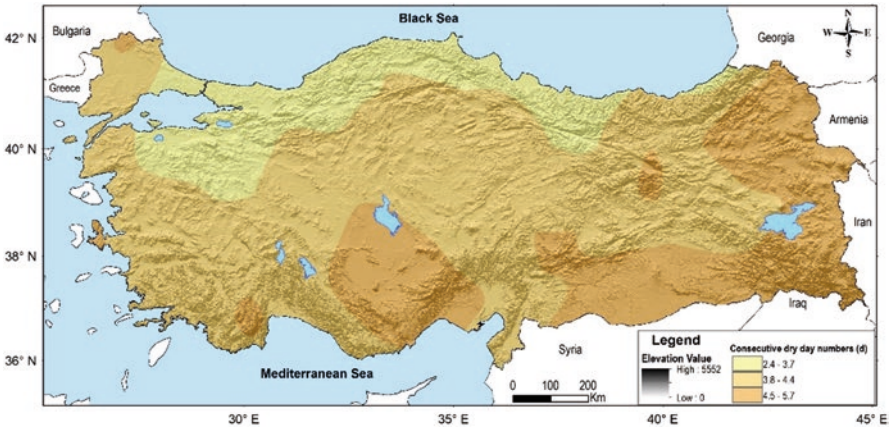

Fig. 8.11 Spatial distribution of consecutive dry day index

8.3.4 Consecutive Dry Days

Consecutive dry days are the days when the precipitation is <1 mm for each weather station and 5 consecutive days are less than 1 mm. The number of consecutive dry days throughout the winter season is between 2.4 and 5.6 days. The number of consecutive dry days is highest in stations found in northeastern of Turkey and Southeastern Anatolia Region and behind the Mediterranean coast. There is an overall upward trend in consecutive dry days in Turkey (Fig. 8.11). A significant upward trend is also observed in the western part of Southeastern Anatolia, especially in the interior areas where terrestrial effects are clear.

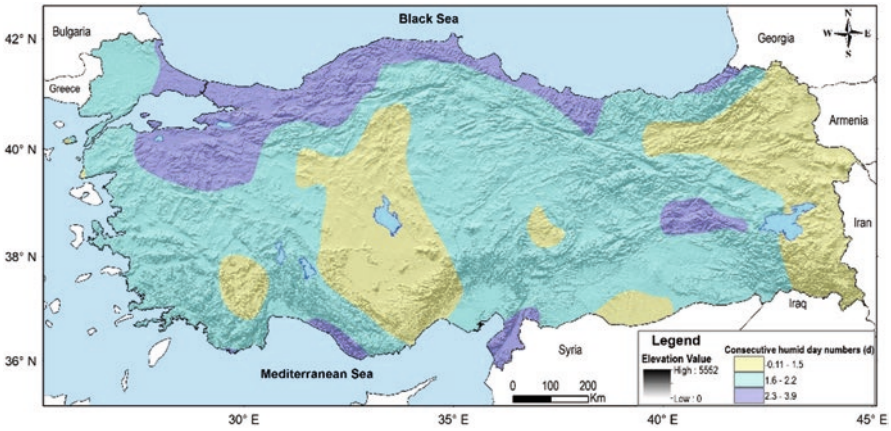

Fig. 8.12 Spatial distribution of consecutive humid day index

8.3.5 Consecutive Humid Days

Consecutive humid days are defined as the number of days in which the precipitation is ≥1 mm and rainfall is greater than or equal to 1 mm for at least 5 consecutive days. The number of consecutive wet winter days in Turkey generally ranges from 0.3 to 3.8. The area with the highest number of consecutive humid days is the Western Black Sea Division of the Marmara Region and the Black Sea Region (Fig. 8.12). This can be explained by the development aspects of depressions that are effective during the winter season. The air masses that are effective over the Balkans are first affected by the north of the Marmara Region and the Western Black Sea. The low number of consecutive humid days in the eastern and eastern parts is related to the snow fall. Turkey has an overall downward trend for consecutive humid days outside of the inner regions.

8.4 Results

The studies show differences in temperature which indicate significant change, especially since the 1990s. According to this assessment, the tendency toward an increase in hot days and a decrease in the number of cold days is noteworthy. These trends have become evident for summer days since the 1990s. The rise in tropical nights has become apparent after the last 5 years of summer days. No significant reduction in frosty and icy days is evident in the last 10 years. This study parallels the studies in the Eastern Mediterranean Basin. Temperature variability and frequencies of extreme events coincide with studies for the Eastern Mediterranean Basin. Although this situation is in parallel with global climate change processes, it

is necessary to take into account the city heat island effect of the meteorological weather stations, especially in the city, in this increase. For example, the upward trend in summer night temperatures or, in other words, summer minimums is an important indicator of the said city heat island effect.

Similar trends are observed in precipitation extremes. Extremely humid days display a weak downward trend in most weather stations in winter. The number of days of rainfall of 20 mm or more shows a weak upward movement in most weather stations in the Black Sea Region (except Hopa, Rize, and İnebolu) and Central Anatolia. In most of the areas dominated by the Mediterranean precipitation regime, a downward trend in very strong precipitation amounts is evident. Trends in the precipitation intensity index are generally increasing.

Consecutive dry days show an overall upward movement in Turkey. A significant upward trend is demonstrated in the western part of Southeastern Anatolia, especially in the interior areas where terrestrial effects are clear. Successive humid days have an overall downward movement outside of the Turkish inland. Accordingly, variability and extreme changes in temperature and rainfall experienced in Turkey are similar to work done on a regional scale. The area impacted alongside the force of extreme weather events with anthropogenic factors and processes like urbanization and the destruction of natural areas is one of the most important threats we face.

References

Acar, Z., & Gönençgil, B. (2019). Extreme precipitation events in Turkey. *Meteorological Journal, 22*(2), 87–94.

Acar, Z., Gönençgil, B., & Korucu Gümüşoğlu, N. (2018). Long-term changes in hot and cold extremes in Turkey. *Journal of Geography, 37*, 57–67.

Alexander, L. V., Zhang, X., Peterson, T. C., Caeser, J., Gleason, B., Klein Tank, A. M. G., Haylock, M., Collins, D., Trewin, B., Rahimzadeg, F., Tagipour, A., Rupa Kumar, K., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D. B., Burn, J., Aguilar, E., Brunet, M., Taylor, M., New, M., Zhai, P., Rusticucci, M., & Vazquez-Aguirre, J. L. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research, 111*, D05. https://doi.org/10.1029/2005JD006290.

Bordi, I., Frigio, S., Parenti, P., Speranza, A., & Sutera, A. (2001). The analysis of the standardized precipitation index in the Mediterranean area: Large-scale patterns. *Annali Di Geofisica, 44*(5/6), 965–978.

Erinç, S. (1996). *Climatology and methods* (Geography. Series no:1) (276th ed.). İstanbul: Alfa Printing Broadcasting Publication Distributing.

Erlat, E., & Türkeş, M. (2015). Observed changes in the frequencies of record maximum and record minimum air temperatures in Turkey during the period 1950–2014 and their connections with atmospheric conditions. *Ege Coğrafya Dergisi, 24*(2), 29–55.

Erlat, E., & Yavaşlı, D. D. (2009). Ege Bölgesi'nde tropikal gün ve yaz günü sayılarındaki değişim ve eğilimler. *Ege Coğrafya Dergisi, 18*, 1–2),1-15.

Erol, O. (1999). *General climatology* (5th ed.). İstanbul: Çantay Bookstore.

Fernández-Montes, S., & Rodrigo, F. S. (2012). Trends in seasonal indices of daily temperature extremes in the Iberian Peninsula, 1929–2005. *International Journal Climatology, 32*(15), 2320–2332. https://doi.org/10.1002/joc.3399.

Frich, P., Alexander, L. V., Della-Marta, P., Gleason, B., Haylock, M., Klein Tank, A. M. G., & Peterson, T. (2002). Observed coherent changes in climatic extremes during the second half of the twentieth century. *Climate Research, 19*(3), 193–212. https://doi.org/10.3354/cr019193.

Gönençgil, B. (2008). *Doğal Süreçler Açısından İklim Değişikliği ve İnsan*. İstanbul: Çantay Yayınevi.

Gönençgil, B. (2019). Evaluate Turkey's climate classification by clustering analysis method. In S. Nedkov, G. Zhelezov, N. Ilieva, M. Nikolova, B. Koulov, K. Naydenov, & S. Dimitrov (Eds.), *Smart geography* (pp. 41–53). Springer.

Gönençgil, B., & Acar Deniz, Z. (2016). *Atmospheric disasters and extreme weather events*. Istanbul: Çantay Publishing. (in Turkish).

Hare, F. K. (1991). Contemporary climatic change: The problem of uncertainty. In B. Mitchell (Ed.), *Resource management and development: Addressing conflicts and uncertainty* (pp. 8–27). Oxford: Oxford University Press.

Kendall, M. G. (1975). *Rank correlation methods* (4th ed.). Oxford: Charles Griffin.

Klein Tank, A. M. G., & Können, G. P. (2003). Trends in indices of daily temperature and precipitation extremes in Europe 1946–1999. *Journal of Climate, 16*(22), 3665–3680. https://doi.org/10.1175/1520-0442(2003)016<3665:TIIODT>2.0.CO;2.

Koçman, A. (1993). *Türkiye İklimi*. İzmir: Ege Üniversitesi Edebiyat Fakültesi Yayınları No: 72.

Livada, I., & Assimakopoulos, V. D. (2007). Spatial and temporal analysis of drought in Greece using the Standardized Precipitation Index (SPI). *Theoretical and Applied Climatology, 89*, 143–153.

Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., & Wanner, H. (2004). European seasonal and annual temperature variability, trends, and extremes since 1500. *Nature, 303*, 1499–1503. https://doi.org/10.1126/science.1093877.

Mann, H. B. (1945). Non-parametric test against trend. *Econometrika, 13*, 245–259.

Şensoy, S., Demircan, M., & Alan, I. (2008). Trends in Turkey Climate Extreme Indicesfrom 1971 to 2004. IV. Atmosfer Bilimleri Sempozyumu (25–28 Mart 2008). *Bildiri Kitabı, 453–460*, 2008.

Smithers, J., & Smit, B. (1997). Human adaptation to climatic variability and change. *Global Environmental Change, 7*(2), 129–146.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: A review. *Global Change Biology, 20*(11), 3313–3328. https://doi.org/10.1111/gcb.12581.

Ünal, Y. S., Tan, E., & Menteş, S. (2012). Summer heat wave over western Turkey between 1965 and 2006. *Theoretical and Applied Climatology, 112*(1–2), 330–350. https://doi.org/10.1007/s00704-012-0704-0.

Vicente-Serrano, S. M., & Lopez-Moreno, J. I. (2005). Hydrological response to different time scales of climatological drought: An evaluation of the Standardized Precipitation Index in a mountainous Mediterranean basin. *Hydrology and Earth System Sciences, 9*(5), 523–533. https://doi.org/10.5194/hess-9-523-2005.