

ASSESSMENT OF CHANGES IN CLIMATE INDICES OF THE
MEDITERRANEAN CLIMATE REGION OF TURKEY

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MEDITERRANEAN CLIMATE REGION OF TURKEY**

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ABSTRACT

ASSESSMENT OF CHANGES IN CLIMATE INDICES OF THE MEDITERRANEAN CLIMATE REGION OF TURKEY

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As a consequence of climate change, frequency and intensity changes in extreme weather events have occurred. One of the most vulnerable regions of the world that is affected by the climate change is the Mediterranean region. Turkey as a Mediterranean country has a great importance to investigate the changes in climate behavior. 57 stations from Mediterranean climate region of Turkey have been selected as the study area for this thesis. This study aims to assess the climate indices that carry the valuable information about the climate of a region and detect trends and anomalies in those climate indices, precipitation and temperature patterns. 8 different General Circulation Model/Regional Climate Model couplings obtained from CORDEX project have been used in this study to make predictions on the period of 2011-2050. To evaluate the model performance and determine the most appropriate model, observed data and model data have been compared for the reference period 1971-2005. Five groups of climate indices which are percentile-based indices, absolute indices, threshold indices, duration indices and other indices have been calculated. The trends in climate indices, precipitation and temperature have been determined by applying the Mann-Kendall trend test. According to the results of the analyses, there are significant warming trend in temperature and

temperature-related indices through the whole region and mixed pattern in precipitation and related indices.

Keywords: Climate Change, Climate Indices, Mediterranean Climate Region, CORDEX Project, Trend Analysis



ÖZ

TÜRKİYE AKDENİZ İKLİM BÖLGESİ İKLİM ENDEKSLERİNDEKİ DEĞİŞİKLİKLERİNİN DEĞERLENDİRİLMESİ

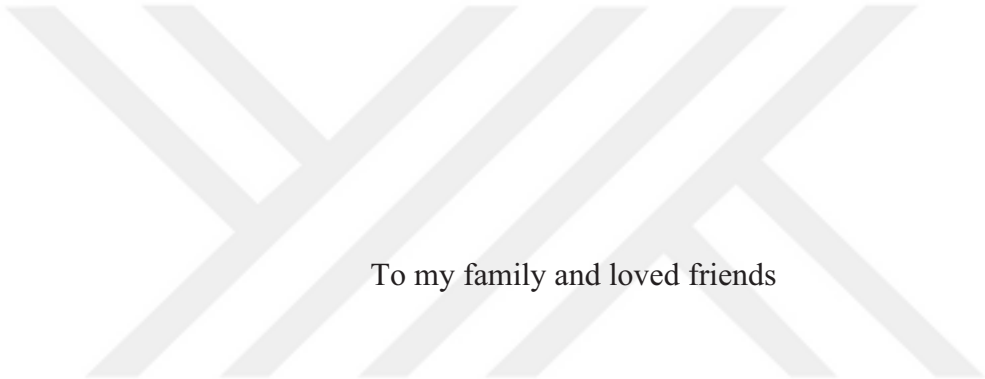
Çetinkaya, İzem
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Eylül 2020, 149 sayfa

İklim değişikliğinin bir sonucu olarak, aşırı hava olaylarında sıklık ve yoğunluk anlamında değişiklikler meydana gelmektedir. Akdeniz Bölgesi iklim değişikliğinden etkilenen dünyadaki en hassas bölgelerden biridir. Bir Akdeniz ülkesi olarak Türkiye, iklim davranışındaki değişikliklerin araştırılması açısından büyük öneme sahiptir. Türkiye'nin Akdeniz iklimi bölgesinden 57 istasyon bu tez için çalışma alanı olarak seçilmiştir. Bu çalışma, bölgenin iklimi hakkında değerli bilgiler taşıyan iklim endekslerinin değerlendirilmesini ve bu iklim endeksleri ile, yağış ve sıcaklık desenlerindeki trendleri ve anormallikleri belirlemeyi amaçlamaktadır. 2011-2050 dönemine ilişkin tahminlerde bulunmak için, bu çalışmada, CORDEX projesinden elde edilen 8 farklı Küresel Dolaşım Modeli/Bölgesel İklim Modeli birleşimi kullanılmıştır. Model performansını değerlendirmek ve en uygun modeli belirlemek için, gözlemlenen veriler ve model verileri 1971-2005 referans dönemi için karşılaştırılmıştır. Yüzdelik temelli endeksler, mutlak endeksler, eşik endeksleri, süre endeksleri ve diğer endeksler olmak üzere beş grup iklim endeksi hesaplanmıştır. İklim endeksleri, yağış ve sıcaklıktaki trendler Mann-Kendall trend testi uygulanarak belirlenmiştir. Analiz sonuçlarına göre, tüm bölge genelinde sıcaklık ve sıcaklığa bağlı endekslerde önemli bir ısınma eğilimi ve yağış ve ilgili endekslerde karışık desen görülmektedir.

Anahtar Kelimeler: İklim Değişikliği, İklim Endeksleri, Akdeniz Bölgesi,
CORDEX Projesi, Trend Analizi





To my family and loved friends

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CCI	Commission for Climatology
CLIVAR	Climate Variability and Predictability
CORDEX	Coordinated Regional Climate Downscaling Experiment
ETCCDMI	Expert Team on Climate Change Detection, Monitoring and Indices
GCM	General Circulation Model/Global Climate Model
IPCC	Intergovernmental Panel on Climate Change
NASA	The National Aeronautics and Space Administration
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RMSE	Root Mean Square Error
TSMS	Turkish State Meteorological Service
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

1.1 Introduction

Observed from space, our home planet Earth attracts the attention with its abundance of water. Water is essential to sustaining life, and is the link between the Earth's components, lands, oceans and atmosphere. It evaporates from the ocean and land surfaces to the atmosphere, cools and condenses there, and comes back to the surface as precipitation. As this never-ending global process continues, it causes energy exchanges between the components of Earth and determines the Earth's climate (WEB1).

Climate is the average weather of a given region for a long period of time. A climate gives information about, e.g. seasonal rainfall amount, average temperature of a season. While the weather can change in minutes or hours, the climate changes over decades or centuries (WEB2). As stated in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), our climate and its extremes are changing (Stocker et al., 2013).

One of the major points of climate change studies is description of the behavior of extreme weather events (Fallah-Ghalhari et al., 2019). Figure 1 shows a clear representation of the question of what are the extremes. Climate change resulting from human affects has caused to changes in the frequency and intensity of extreme events. Two aspects of climate that may be influenced by climate changes are extreme temperature and precipitation events, so necessary preparation must be made to overcome these extreme events that may affect the population, infrastructures, systems and other sectors (López-Díaz et al., 2013).

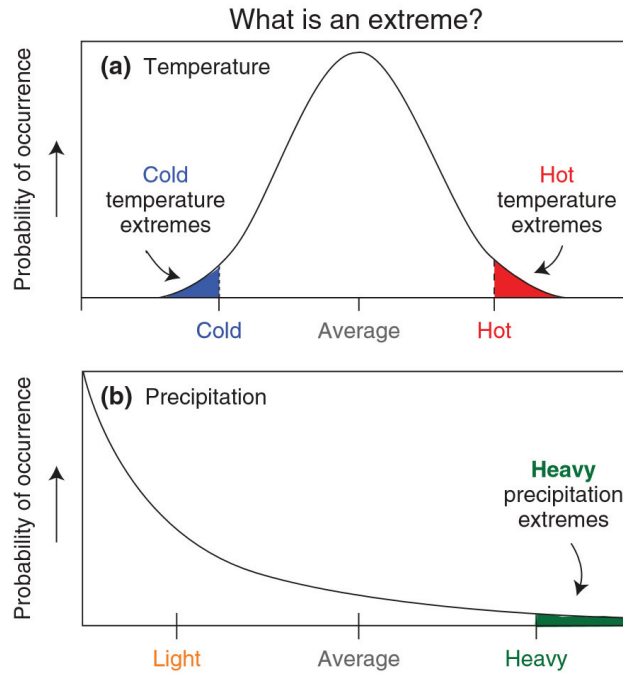


Figure 1.1. The probability distributions of daily temperature and precipitation. Extremes are shown by the shaded areas (Zhang et al., 2011).

To understand behavior of climate and make prediction on it, scientists use climate models. Models allow to draw conclusions on past and future climate. They are based on physical processes to simulate the energy and material transfer over the climate system (WEB3). There are many climate models, also known as general circulation models (GCMs), they can serve reliable prediction on scales of around 1000 by 1000km, so GCMs have low spatial resolution. Regional Climate Models (RCMs) applied over a limited spatial domain at a higher resolution than GCMs and driven by GCMs can give information on smaller scales. This enables to make more detailed impact assessment and planning for many vulnerable regions of the world (WEB4). In this study, 8 GCM-RCM couplings were used for the model data and detailed information was provided in section 2.1.3.

IPCC has indicated that the Mediterranean Basin is one of the most vulnerable areas of the world to climate change (Thiébaud, 2016). Turkey is located in Mediterranean

Basin, and the Mediterranean climate region is affected more by climate change and its extremes than the other regions of the country in terms of being a coastline to the basin.



Figure 1.2. Satellite image of Turkey (Captured from Google Earth)

Turkey is located between temperate zone and subtropical zone. Surrounding three side of Turkey by the sea, the existence of the mountains that run parallel to the coasts and variety of land forms cause having different types of climate over the country. The geography of Turkey can be seen from the satellite image in Figure 1.2. Temperate climate features occur in the coastal zones of Turkey by the effects of the sea. Although the coastal zones show milder climate behavior, the inland Anatolian plateau has extremes of hot summers and cold winters with limited rainfall (Sensoy et al., 2016). 2019 has been the year having the highest extreme event (h. rain, floods, wind storm, hail, frost, heat/cold wave, landslide etc.) occurrence with the number of 935 and there is an increasing in extreme event trends, especially in the last 20 years (Figure 1.3) (TSMS Research Dept., 2020). Changing of the climate behavior and extreme events over the country in terms of occurrence, duration and frequency will affect the society in many aspects. To understand this change and combat the

impacts of it, climate variables and indices are need be addressed clearly. Over the past decades, the trend of temperature and precipitation extremes has been the topic

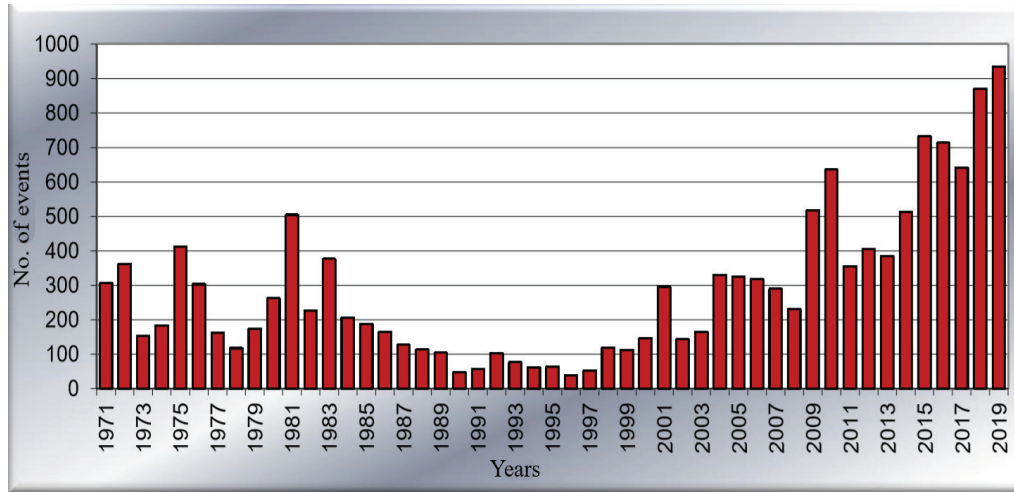


Figure 1.3. Annual number of extreme events in Turkey in 1971-2019 (TSMS Research Dept., 2020)

of research by many scientists. Daily data sets of precipitation and temperature have been not sufficient to come to a more precise conclusion on climate change and its extremes and to this end, indicators of climatic extremes have been developed by a few of international workshops (Frich et al., 2002). The joint World Meteorological Organization (WMO) Commission for Climatology (CCI)/World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR) Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) took in charge the international coordination of the development of a set of indices for climate change. Besides ETCCDMI members, many other scientists involved to this study and they defined 27 indices and developed two software packages which are freely available (Alexander et al., 2006). Within the scope of this thesis, 23 of them annually, and 18 of them seasonally were examined for the 57 stations located in the Mediterranean climate region of Turkey. As a result of the analyses, mostly increasing trend in warmth was observed over the region, while a mixed pattern in precipitation and related indices. Results of the analyses were presented in Chapter 3.

1.2 Significance of the Study

Mediterranean Basin is located in a transition zone between the mild and rainy climate of central Europe and dry climate of North Africa and the basin is affected by interactions between tropical and mid-latitude processes. These features cause climate of the region to be changed considerably by the minor modifications of the general circulation, e.g. shifts in the location of sub-tropical high-pressure cells. Future projections show that Mediterranean region will be harshly affected by changes in terms of both temperature and precipitation. According to studies conducted on Turkey, this is also the case in Mediterranean Climate Region of the country (Dabanlı et al., 2017; Türkeş, 1999; Türkeş & Erlat, 2003). These studies show that climate extremes in the Mediterranean climate region of Turkey, including the Aegean region, the Mediterranean region and the southern Marmara region, are significantly intensified. So that, 57 stations located in this region have been selected as the study area for the thesis. To reveal the current situation and predict the future, analyses have been performed for baseline (1970-2011) and mid-century (2011-2050) periods. 23 climate indices defined by ETCCDI have been used to explain the change of extremes in the obvious way. Those indices consist of 7 precipitation and 16 temperature indices. This thesis differs itself from other studies in terms of both annual and seasonal analyses with the variety and abundance of indices used, and it has great importance for examining the region in a more comprehensive manner. It is aimed to show spatial distributions and patterns of indices and its trends more clearly by presenting them with maps.

1.3 Literature Review

As stated in the Fifth Assessment Report of IPCC (2013), it is obviously seen that the global climate system is warming. Global warming can be defined as the rising of global average temperature by the effect of increasing amount of carbon dioxide in the atmosphere. According to report, the global average combined land and ocean

surface temperature show increasing trend by the value of 0.85 [0.65 to 1.06] °C, over the period 1880-2012. The difference between the average of the 1850-1900 period and the 2003-2012 period is 0.78 [0.72 to 0.85] °C. It may seem advantageous for who lives in cooler climates at first view, but the warming changes the global climate and causes increasing in extreme weather events in terms of occurrence, intensity and duration.

The term “extreme events” refers to infrequent events approaching the far tails of the probability distribution. Both maximum and minimum temperature extremes have risen over land areas since the mid-20th century, while the number of cold days and nights decline, it is seen that the number of warm days and nights increase. Although the temperature shows the increasing trend on global scale, precipitation extremes vary from region to region. Precipitation is likely to increase in the polar areas, northern Europe, Canada, northern Asia but decreases in many subtropical regions, European and African regions bordering the Mediterranean (Solomon et al., 2007; Stocker et al., 2013).

Changes in the extreme precipitation events are derived from several reasons but the atmospheric and the oceanic circulations, as the phrase is, take the biggest slice of the cake. Fluctuations in those circulations are important elements of climate (Folland et al., 2002). El Niño-Southern Oscillation (ENSO) is the primary global driver affecting the climate variability which occurs in the 2 to 7-year time span and commonly lasts 12-18 months. El Niño can be defined as warming of the sea surface temperatures (SST) anomalously in the Pacific Ocean of Southern Hemisphere, while the Southern Oscillation Index (SOI) is the measure of air pressure existing in the Pacific-Indian Ocean region. The frequency and intensity of the ENSO events have been unexpected since the middle of the 1970s compared with the past 100 years. The warm phase of ENSO (El Niño) has shown up more frequently with high intensity than the cold phase (La Niña) during this period (Folland et al., 2002; Solomon et al., 2007). As a consequence of this change in ENSO events, extreme weather events show unusual behavior, particularly in the vulnerable areas against climate change.

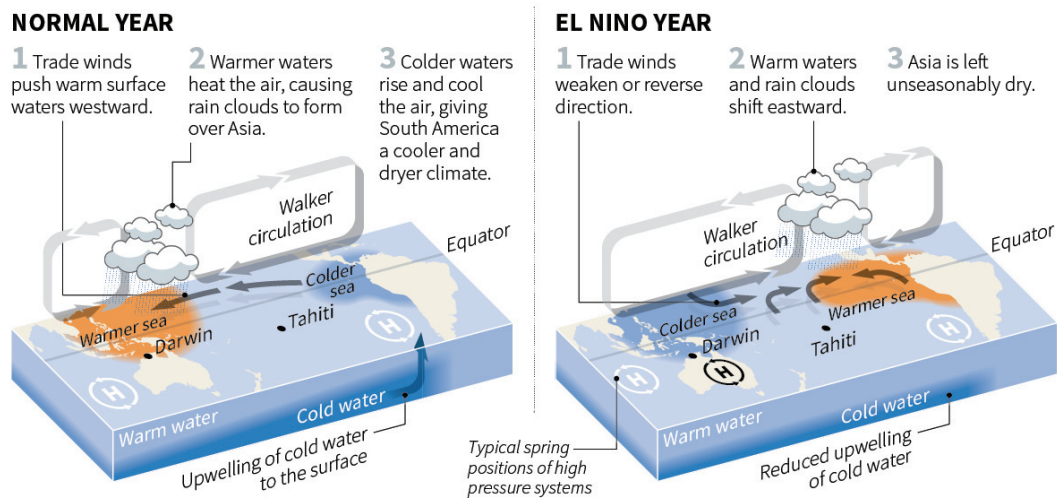


Figure 1.4. The ocean and atmospheric circulation during El Niño events

(Source: NOAA; Australia Bureau of Meteorology By Wen Foo and Travis Hartman | REUTERS GRAPHICS) (WEB10)

The location of the Mediterranean region is in a transition zone between the moderate and rainy climate of Central Europe and the dry climate of North Africa. While the northern part of the region is affected by the North Atlantic Oscillation (NAO), the southern part is under the influence of the descending branch of the Hadley cell in the almost whole year, and precipitation is mainly linked to El Niño-Southern Oscillation (ENSO) (Giorgi & Lionello, 2008; Lionello et al., 2012). In the studies conducted on this region, it is agreed that the Mediterranean is one of the most prominent and sensitive regions facing climate change. Analyses based on observation data point that the Mediterranean is inclined to be warmer and drier over the second half of the century, and it is stated that while increases in precipitation are observed over the northern part of the region, there will be decreases in the southern part. The region has already been experienced extreme climate and weather events over the years such as the hottest summer 2010 (Folland et al., 2002; Giorgi, 2006; Kim et al., 2019; Thiébault, 2016).

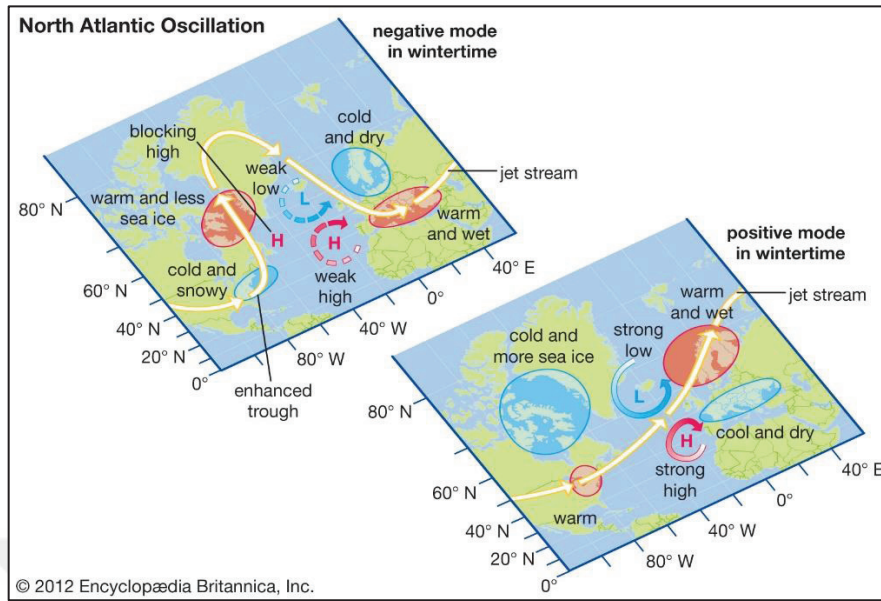


Figure 1.5. The two phase of the North Atlantic Oscillation (NAO) (WEB11)

In several studies, the Mediterranean region is investigated in terms of weather events in changing climate and it is concluded that the region will be warmer and drier by the end of the century (Adloff et al., 2015; Hertig & Jacobeit, 2008; Ozturk et al., 2018; Somot et al., 2008). Fallah-Ghalhari et al. (2019) have studied on the trends of maximum and minimum temperatures in Iran to see climate change impacts. They have indicated that warm days (TX90) and warm nights (TN90) showed a significant positive trend. According to the study of Pereira et al. (2019), the Iberian Peninsula tends to experience substantial reduction in annual precipitation by the end of the century under climate change, but the precipitation will be more intense. The precipitation in the Mediterranean will mainly decrease in wintertime over the Balkan and Italian peninsulas, in the southern Anatolian coast and northwest Africa (Xoplaki, 2002).

Many studies have performed in Turkey, one of the Mediterranean subtropical countries, to detect precipitation and temperature variations under climate change. Turkey is likely to be affected negatively by climate change with regards to surface

water (Yilmaz & Yazicigil, 2011; Yucel et al., 2015). According to various model outputs, Turkey will have a warmer and drier climate type in the immediate future compared to the reference period (Turp et al., 2015). In the end of 20th century, Türkeş (1999) has stated that annual and winter precipitation show significant decreasing trend in the Aegean and Mediterranean region of Turkey. In the study of Sensoy et al. (2007), they analyzed 100 stations in Turkey in terms of climate extremes for the period between 1971 and 2004, and the results showed that the number of tropical nights and summer days has been increasing in every station while ice days and frost days decreasing. Moreover, it is pointed that the mean annual total precipitation declined in 30 stations located in Aegean and inland Anatolia, but in general, there are different patterns in precipitation. In another study, monthly rainfall and temperature data of 33 stations from Central Anatolia has been examined for the period of 1975-2007. A significant increasing in annual temperature by the value of 0.4°C, decreasing in mean rainfall intensity in the southern parts of the region and increasing in the northern parts have been detected. Increasing trend of rainfall in the north of the region has been observed in summer and autumn while decreasing in winter and spring (Altın et al., 2012). The results of the study conducted on the Eastern Mediterranean and the Middle East have indicated that hot summer conditions which occurred infrequently may turn into the norm by the middle of the 21st century. And, annual precipitation is likely to decrease in the southern Europe-Turkey region (Lelieveld et al., 2012). Erlat & Türkeş (2013) have concluded that increasing trend of summer temperature in the Eastern Mediterranean region indicates increasing of extreme high temperatures and longer heat-waves. As a consequence of the studies, it can be said that Turkey will become a warmer country with rising temperatures. And, precipitation varies over the regions seasonally, there is a decreasing trend in the south while increasing in the north.

The studies have been done so far have remarkable contribution to literature in the subject of climate change impacts in Turkey by using climate indices. Nevertheless, there is still a gap in the literature in studies on Turkey (especially studies on

Mediterranean climate region) in terms of variety of indices used and actuality of data.

1.4 Description of Thesis

A brief information about climate change and its impacts on the weather events is given in the first chapter. Previous studies on this subject are also mentioned within this chapter. Detailed information of data, study area and methods used are stated in the second chapter. The following chapter contains results of the study. In the fourth chapter, the results are discussed. And in the last chapter of the thesis, summary, conclusions and recommendations are given.

CHAPTER 2

STUDY AREA, DATA AND METHODS

2.1 Study Area and Data

2.1.1 Study Area

The Mediterranean region is located between subtropical zone (south) and temperate zone (north) and the characterization of the region is directly associated with Mediterranean Sea (Lionello et al., 2012).

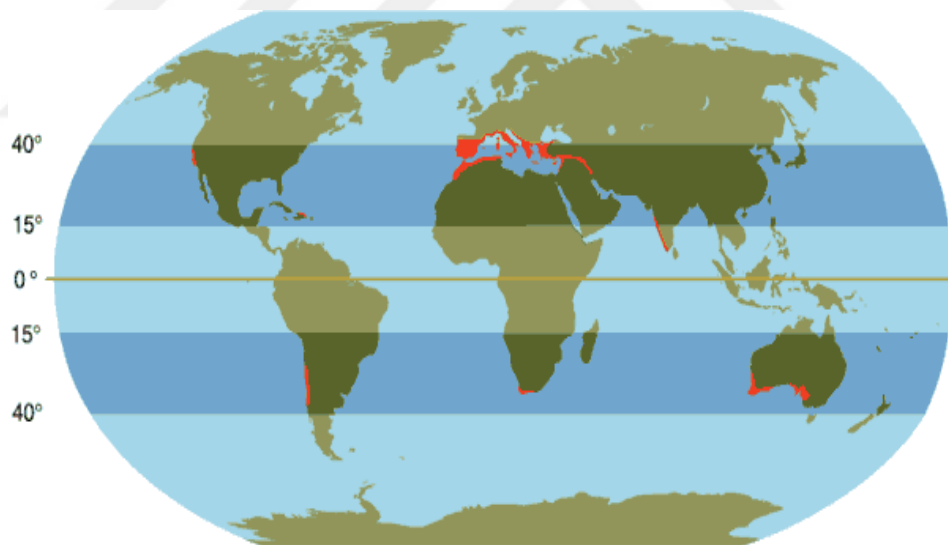


Figure 2.1. Areas with Mediterranean climate are highlighted by red color (WEB12).

In general, summers are hot and dry, and winters are cool and wet in the region. However, the different climate types are observed through the region by the effect of various atmospheric and oceanic circulations (Lionello et al., 2012).

The Mediterranean is the one of the most prominent regions which is vulnerable to climate change and the change in climate behavior has shown itself since the end of 20th century. Beside the rising temperature in all seasons, the greatest change is a considerable decrease in mean precipitation and an increase in precipitation fluctuation over the dry season (Giorgi, 2006).

Köppen climate types of Turkey

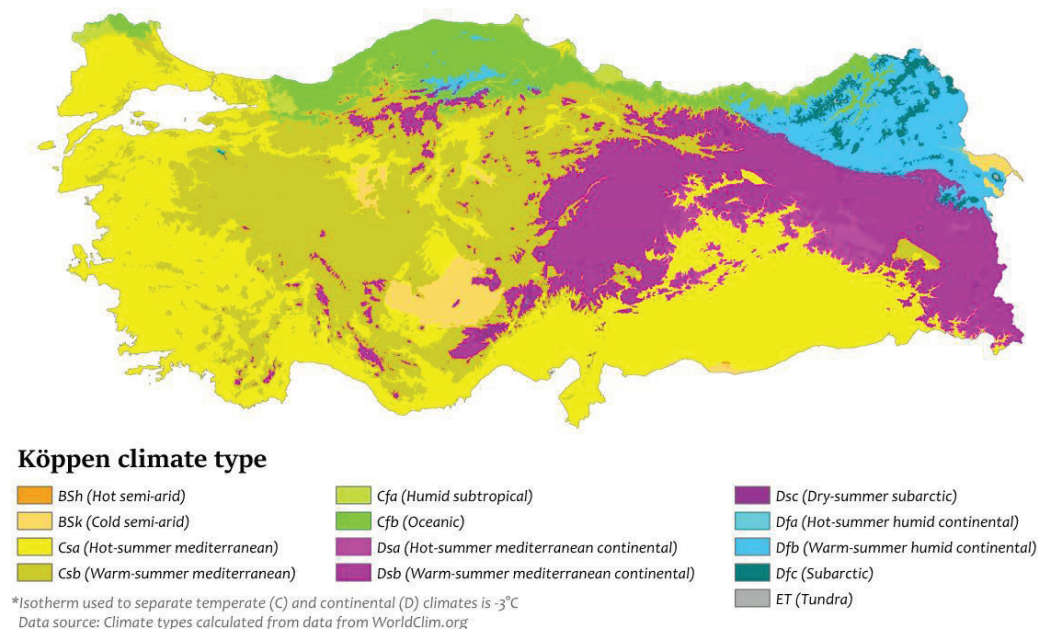


Figure 2.2. Climate types of Turkey (WEB13)

Turkey is located in Mediterranean Basin, between temperate zone and subtropical zone. Three sides of the country are surrounded by the sea which are the Black Sea in the north, the Aegean Sea in the west and the Mediterranean Sea in the south. The existence of the seas and mountains and the variety in the landforms cause the occurrence of various climate types over the country (Figure 2.2.). Turkey receives precipitation mostly in the winter season. The Aegean and Mediterranean coasts experience rainy, cool winters and hot, dry summers. Annual precipitation varies

from 580 to 1,300 millimeters in those coastal areas. The Eastern Black Sea coast receives rainfall almost 2,200 millimeters annually, and that region is the only part of Turkey that has rainfall all the year round (Figure 2.3.) (Sensoy et al., 2016).

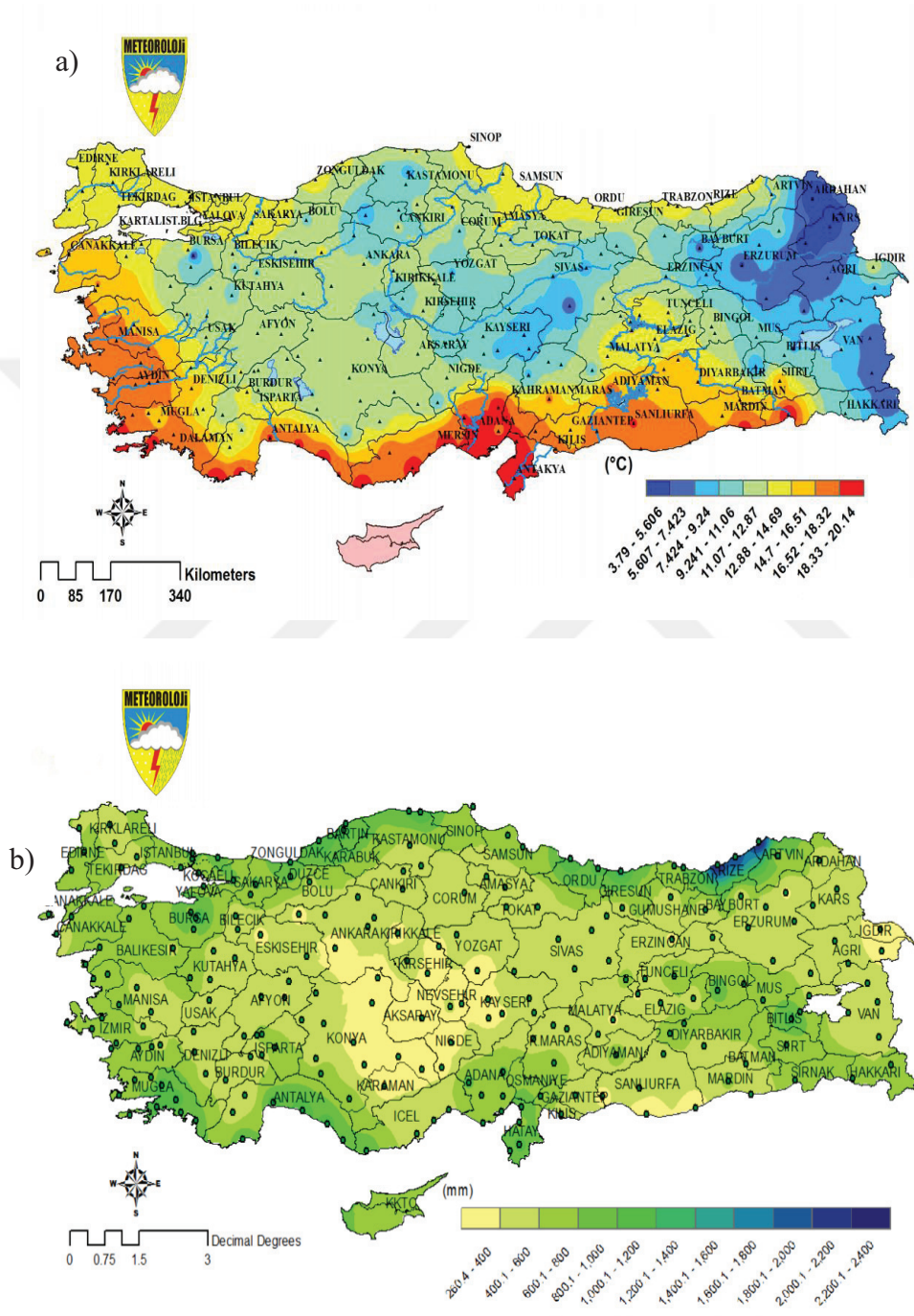


Figure 2.3. The distribution of annual mean temperature (a) and annual total rainfall (b) of Turkey in the period of 1970-2019 (WEB14,15)

2.1.2 Observation Data

Daily observation data of precipitation, minimum and maximum temperature for the period of 1970-2011 have been acquired from TSMS (Turkish State Meteorological Service) for 57 stations that having the Mediterranean climate. Station information is given in Table 2.1 and the spatial distribution of the stations in Figure 2.4.

Table 2.1 Information of the observation station

Station Name	Latitude	Longitude	Station Name	Latitude	Longitude
ACIPAYAM	37.42	29.33	IZMIR	38.43	27.17
ADANA	37	35.33	KAHRAMANMARAS	37.6	36.93
AKHISAR	38.92	27.85	KARAIHALI	37.27	35.07
ANAMUR	36.08	32.83	KARAMAN	37.18	33.22
ANTAKYA	36.2	36.17	KARATAS	36.57	35.38
ANTALYA	36.88	30.7	KILIS	36.72	37.12
AYDIN	37.85	27.85	KOCAELI	40.78	29.93
AYVALIK	39.32	26.7	KORKUTELI	36.75	30.2
BALIKESIR	39.63	27.88	KOZAN	37.45	35.82
BANDIRMA	40.35	27.97	KUSADASI	37.87	27.25
BODRUM	37.05	27.43	MANAVGAT	36.78	31.43
BURDUR	37.72	30.28	MANISA	38.62	27.43
BURSA	40.18	29.07	MARMARIS	36.85	28.27
CANAKKALE	40.15	26.42	MERSIN	36.8	34.6
CEYHAN	37.03	35.82	MILAS	37.32	27.78
DALAMAN	36.75	28.78	MUGLA	37.22	28.37
DATCA	36.75	27.67	NAZILLI	37.92	28.32
DENIZLI	37.78	29.08	NIGDE	37.97	34.68
DIKILI	39.07	26.88	ODEMIS	38.23	27.97
DORTYOL	36.85	36.22	SALIHLLI	38.48	28.13
ELMALI	36.75	29.92	SAMANDAG	36.08	35.97
ERDEMLI	36.62	34.3	SEFERIHISAR	38.35	26.83
FETHIYE	36.62	29.12	SILIFKE	36.38	33.93
FINIKE	36.3	30.15	TEFENNI	37.32	29.77
GAZIANTEP	37.07	37.38	TEKIRDAG	40.98	27.55
GAZIPASA	36.27	32.32	USAK	38.68	29.4
ISKENDERUN	36.58	36.17	YATAGAN	37.35	28.13
ISLAHIYE	37.03	36.63	YUMURTALIK	36.77	35.78
ISPARTA	37.77	30.55			

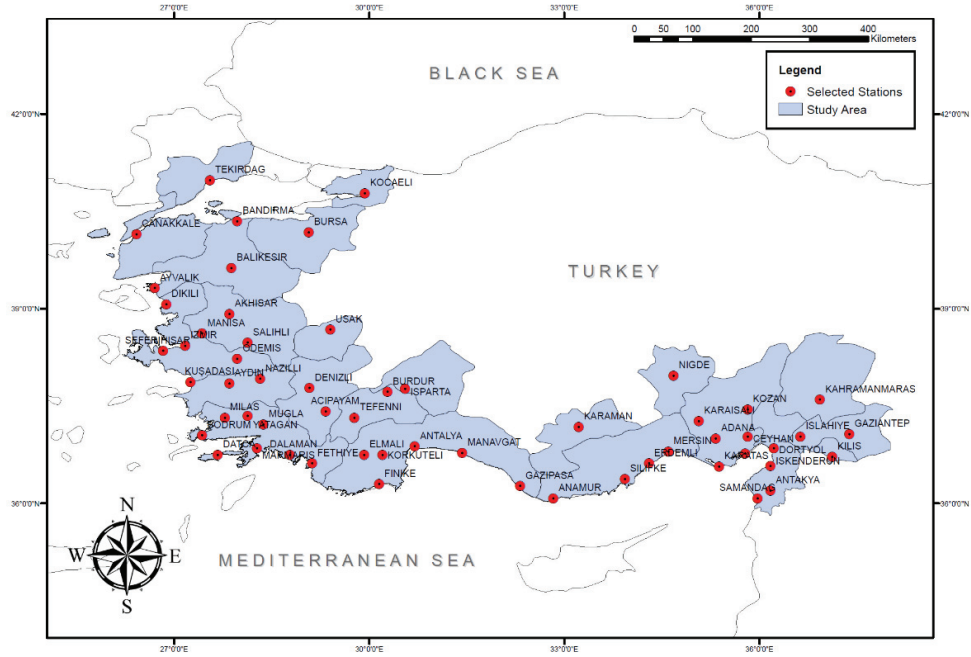


Figure 2.4. Spatial distribution of the observation stations

Quality check for observation data have been done by using ClimPACT2 software. Once uploading data into the software, it calculates thresholds and complete quality control checks. After the calculation, it creates quality control files which contain graphical (plots of daily time-series of temperature and precipitation) and numerical information (as tables). Those files are checked by using the steps provided in the manual of software which is composed by Alexander & Herold (2016). Monthly indices are calculated if no more than 3 days are missing in a month, while annual values are calculated if no more than 15 days are missing in a year. No annual value will be calculated if any 1 month's data are missing.

2.1.3 Model Data

Model data has been obtained from the EUR-11 domain in 0.11° (~ 12.5 km) resolution that is freely available through the Earth System Grid Federation (ESGF) under the CORDEX project (Figure 2.5).

Eight model couplings have been used to obtain model data, and the model list is given in Table 2.2. RCM-GCM couplings have been made of four different GCMs as driving models and four different RCMs.

Table 2.2 Model list used for future projection (“Model no” numbering has been given to provide convenience through the thesis).

Model No	GCM	RCM
1-1	ICHEC-EC-EARTH	RACMO22E
2-1	CNRM-CERFACS-CNRM-CM5	CCLM4-8-17
2-2		RCA4
3-1	MOHC-HadGEM2-ES	CCLM4-8-17
3-2		RACMO22E
3-3		RCA4
4-1	IPSL-IPSL-CM5A-MR	RCA4
4-2		WRF331F

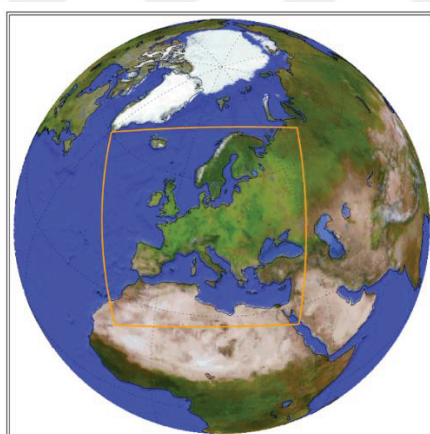


Figure 2.5. EURO-CORDEX domain area indicated by orange square (WEB16).

In impact modeling studies, bias adjustment has been added to the pre-processing of climate simulations to avoid errors in the raw data (Nikulin & Legutke, 2016). Thus, bias-adjusted data by a few different methods has been used in the thesis, and this data is also available on ESGF under the CORDEX-Adjust project. RCP8.5 (Representative Concentration Pathway) that corresponds to the pathway with the highest greenhouse gas emissions has been considered for future projection (Riahi et al., 2011). The most representative grids for each observation station are used for

extraction of the data. The nearest neighborhood method is used when obtaining the gridded stations.

2.2 Methods

2.2.1 Climate Indices

Indices for climate extremes have been used for a long time to obtain important information contained in daily data. In the IPCC Second Assessment Report (SAR, 1995), it is stated that the available data on climate extremes and variability is not enough to say anything about the global changes, even though some regions have experienced the changes in extreme events with the sufficient data (Houghton et al., 1996). Therefore, it has been given priority to studies on the key variables to accelerate the detection and attribution of changes in climate extremes. For his purpose, WMO (the World Meteorological Organization) WCRP (World Climate Research Programme) project for climate variability and predictability (CLIVAR) and GCOS (Global Climate Observing System) organized an international workshop on Indices and Indicators for Climate Extremes in 1997 to promote the researches on data sets and analysis techniques to detect changes in climate extremes. In 1999, CCI (WMO Commission for Climatology)/CLIVAR/JCOMM (Joint WMO–IOC [United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Oceanographic Commission] Technical Commission for Oceanography and Marine Meteorology) Expert Team on Climate Change Detection and Indices (ETCCDI) started to study on this subject. They developed a set of indices consisting of 27 descriptive indices (Zhang et al., 2011). Many studies have been conducted on climate extremes by using the climate indices for various regions (Alexander et al., 2006; Donat, Alexander, Yang, Durre, Vose, & Caesar, 2013; Donat, Alexander, Yang, Durre, Vose, Dunn, et al., 2013; dos Santos et al., 2011; Frich et al., 2002; Keggenhoff et al., 2014; Lestari et al., 2019; López-Díaz et al.,

2013; Zhang et al., 2005, 2011). 23 of those indices have been used for the thesis and the detailed information about those indices is given in Table 2.3.

Indices can be divided into five different groups: percentile-based indices, absolute indices, threshold indices, duration indices and other indices. Percentile-based indices include the occurrence of cool days (TX10), occurrence of hot days (TX90), occurrence of cold nights (TN10), occurrence of hot nights (TN90) and very wet days (R95p). The temperature percentile-based indicators (TX10, TX90, TN10, TN90) enable to assess the extent of changing extremes and precipitation percentile-based indicator (R95p) shows the amount of rainfall above the 95th percentile and include the most extreme events within a year. Absolute indices show minimum or maximum values during a season or year. They comprise maximum value of daily maximum temperature (TXx), minimum value of daily minimum temperature (TNn), maximum value of daily minimum temperature (TNx), minimum value of daily maximum temperature (TXn) and maximum 5-day precipitation (Rx5day). Threshold indices are described as the number of days that temperature or precipitation value lies above or below a constant threshold. This group of indices includes annual number of frost days (FD), annual number of ice days (ID), annual number of summer days (SU25), annual number of tropical nights (TR) and number of very heavy rain days (R20mm). Duration indices express periods of excessive wetness/dryness, warmth/cold or mildness. Growing season length (GSL), warm spell duration indicator (WSDI), cold spell duration indicator (CSDI), consecutive dry days (CDD) and consecutive wet days fall into the duration indicators category. Other indices that do not fall into any of the above categories comprise indices of diurnal temperature range (DTR), annual total wet days precipitation (PRCPTOT) and annual contribution from very wet days (R95pTOT) (Alexander et al., 2006). The indices have been calculated by using the ClimPACT2 software which is based on the RClimDEX software developed by the WMO CCI/WCRP/JCOMM ETCCDI. ClimPACT2 is a freely available R software package (WEB18) that processes meteorological data (precipitation, daily minimum and maximum temperature) (Alexander & Herold, 2016).

Table 2.3 The extreme temperature and precipitation indices used in the thesis (WEB17).

Indicator	Indicator Name	Definition	Unit
FD	Frost days	Annual number of days when $T_{min} < 0\text{ }^{\circ}\text{C}$	days
ID	Ice days	Annual number of days when $T_{max} < 0\text{ }^{\circ}\text{C}$	days
SU25	Summer days	Annual number of days when $T_{max} > 25\text{ }^{\circ}\text{C}$	days
TR	Tropical nights	Annual number of days when $T_{min} > 20\text{ }^{\circ}\text{C}$	days
GSL	Growing season length	Annual number of days between the first occurrence of 6 consecutive days with $T_M > 5\text{ }^{\circ}\text{C}$ and the first occurrence of 6 consecutive days with $T_M < 5\text{ }^{\circ}\text{C}$ (T_M = Daily mean temperature)	days
TXx	Max T_{max}	Warmest daily T_{max}	$^{\circ}\text{C}$
TNn	Min T_{min}	Coldest daily T_{min}	$^{\circ}\text{C}$
TNx	Max T_{min}	Warmest daily T_{min}	$^{\circ}\text{C}$
TXn	Min T_{max}	Coldest daily T_{max}	$^{\circ}\text{C}$
DTR	Diurnal temperature range	Mean difference between daily T_{max} and daily T_{min}	$^{\circ}\text{C}$
WSDI	Warm spell duration indicator	Annual number of days with at least 6 consecutive days when $T_{max} > 90\text{th percentile}$	days
CSDI	Cold spell duration indicator	Annual number of days with at least 6 consecutive days when $T_{min} < 10\text{th percentile}$	days
TX10	Amount of cool days	Percentage of days when $T_{max} < 10\text{th percentile}$	%
TX90	Amount of hot days	Percentage of days when $T_{max} > 90\text{th percentile}$	%
TN10	Amount of cold nights	Percentage of days when $T_{min} < 10\text{th percentile}$	%
TN90	Amount of hot nights	Percentage of days when $T_{min} > 90\text{th percentile}$	%
CDD	Consecutive dry days	Maximum annual number of consecutive dry days (when $PR < 1.0\text{ mm}$, PR = precipitation)	days
CWD	Consecutive wet days	Maximum annual number of consecutive wet days (when $PR \geq 1.0\text{ mm}$)	days
R20mm	Number of very heavy rain days	Annual number of days when $PR \geq 20\text{ mm}$	days
Rx5day	Max 5-day PR	Maximum 5-day PR total	mm
PRCPTOT	Annual total wet-day PR	Annual sum of daily $PR \geq 1.0\text{ mm}$	mm
R95p	Total annual PR from heavy rain days	Annual sum of daily $PR > 95\text{th percentile}$	mm
R95pTOT	Contribution from very wet days	$100 * R95p / \text{PRCPTOT}$	%

2.2.2 Trend Analysis

For the trend analysis of seasonal climate indices, anomalies, precipitation and temperature changes, the Mann-Kendal test (Mann, 1945; Kendall, 1975) and Sen's slope estimator (Sen, 1968) have been used. Both methods are non-parametric methods that are commonly used to detect trends of variables in hydrology and meteorology (Gocic & Trajkovic, 2013; Koudahe et al., 2017). The Mann-Kendall test statistic S is calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad (1)$$

where n is the number of data points, x_i is the data value at time i and $\text{sgn}(x_j - x_i)$ is the sign function that can be computed as:

$$\text{sgn}(x_j - x_i) = \begin{cases} 1, & \text{if } (x_j - x_i) > 0 \\ 0, & \text{if } (x_j - x_i) = 0 \\ -1, & \text{if } (x_j - x_i) < 0 \end{cases} \quad (2)$$

The variance:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)}{18} \quad (3)$$

where n is the number of data points, m is the number of tied groups and t_i indicates the number of tied values of extend i . For $n > 10$, the test statistic Z roughly follows a standard normal distribution:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases} \quad (4)$$

A positive value of Z indicates an increasing trend while a negative value of Z shows a decreasing trend. Trends is tested at the specific α significance level. The null

hypothesis is rejected and a significant trend exists when $|Z| > Z_{1-\alpha/2}$. 5% significance level is considered in the thesis. When $|Z| > 1.96$ it means that there is a significant trend at 5% significance level (Gocic & Trajkovic, 2013). The magnitude of a time series trend can be indicated by trend slope β :

$$\beta = \text{Median}\left(\frac{x_i - x_j}{i - j}\right), i > j \quad (5)$$

where x_i and x_j are the data values at time i and j ($i > j$), respectively. R function *sens.slope()* has been used for trend tests in the thesis.

2.2.3 Interpolation of Spatial Distribution of Climate Variables

Climate variables are measurable point values that present meteorological condition of a region. One of the most important steps in the evaluation of these data collected in a certain order at meteorological observation stations is to express the point data as spatial distribution. To this end, various spatial interpolation methods have been developed and a vector data can be converted into a raster data by using those methods (Dogru et al., 2011). Spatial distribution of climate variables can be mapped via interpolation methods provided by different Geographical Information Systems (GIS) software. In the thesis, ArcGIS software has been used and Inverse Distance Weighting (IDW) has been selected as the interpolation method. IDW interpolation computes cell values using a linearly weighted combination of sample points. The weight defined for points is a function of inverse distance. In this context, as the distance increases, the effect of the function decreases (WEB19). In the study of Ilker et al. (2019), the most appropriate method for mapping of spatial distribution of rainfall is determined as IDW for Mediterranean region according to the results of accuracy analysis.

2.2.4 Statistics Used for Assessing Model Performance

The performance of the climate models can be evaluated by using the statistical measures and the measures quantify the error in the model (Gleckler et al., 2008; Pincus et al., 2008; Schaller et al., 2011). In the thesis, Root Mean Square Error (RMSE) and Pearson's correlation have been used for the evaluation of reference period 1971-2005. RMSE is a frequently used indicator and it is calculated by the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (O_i - P_i)^2}{N}} \quad (6)$$

where O_i , P_i and N represent the observed data, predicted data and number of data, respectively. It ranges from 0 to ∞ , lower the value of RMSE better the fit of model to data and $RMSE = 0$ means a perfect fit (Gleckler et al., 2008). RMSE has the same units with the response variables, and it is considered as one of the most important criteria to evaluate the accuracy of a model.

The Pearson's correlation coefficient (r) is a method for measuring the statistical relationship and the association between two variables. It can range from -1 to 1, and $r = 1$ means a perfect positive relationship, $r = -1$ means a perfect negative relationship and $r = 0$ means no relationship exists. For N number of data, r is calculated by:

$$r = \frac{\sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^N (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^N (y_i - \bar{y})^2}} \quad (7)$$

where x_i and y_i single values of observed and model data, respectively; $\bar{x}$ and $\bar{y}$ are the sample means of them (Ahlgren et al., 2003).

The values of RMSE and r were calculated for both daily and monthly evaluations at each station, then averaged for the whole region. Models were ranked (with a rank value of 1 being the best) based on RMSE and r as N1 and N2, respectively. Average

of daily and monthly evaluation rank was used to calculate the averaged rank as given in Equation 8.

$$\text{Average Rank} = \text{Average} ((N1, N2)_d, (N1, N2)_m) \quad (8)$$

where d and m denote daily and monthly evaluations, respectively.



CHAPTER 3

RESULTS

3.1 Performance of the Models

At the beginning of the analyses, the observation data and model data of climate variables (precipitation, maximum and minimum temperature) have been compared for the reference period 1971-2005 to show the model performance. The daily and monthly averages of precipitation and temperature data have been compared and the model performance statistics have been assessed. For model data, the comparison between not-bias-adjusted and bias-adjusted data has been also shown in the following graphs. 6 model ensembles from the model list in the Table 2.2 have been available in the CORDEX project website for the not-bias adjusted data. Root Mean Square Error (RMSE) and the Pearson's correlation coefficient (r) indicators recommended by WMO have been used together for evaluation of model performance as the combination of techniques would provide more comprehensive information about the model's ability to mimic observation data (Flato et al., 2013). In addition to graphical comparisons, tables of model performance evaluation statistics (for both daily and monthly evaluation) were given in this section.

3.1.1 Evaluation of Precipitation Data

The plots in the Figure 3.1. demonstrate the comparison between regionally averaged mean daily precipitation from RCMs and observed mean daily precipitation. Both not-bias-adjusted data and bias-adjusted data have been used as model data in this section to compare in terms of suitability for use in the thesis. Model performance statistics have been provided in Table 3.1. Visual examination of Figure 3.1 shows that in spring, daily averages of Model 1-1 for both bias- adjusted and not-bias-

adjusted (Figure 3.1.a) overestimated the observation. Bias-adjusted Model 1-1 in summer and not-bias-adjusted Model 1-1 in winter diverged from the observation. Model 2-1 overestimated the observation in January, spring and summer regardless of bias-adjusted or not (Figure 3.1.b). Model 2-2 (both bias-adjusted and not-bias-adjusted) did not well correlate with the observation means (Figure 3.1.c). Bias-adjusted Model 3-1 overestimated the observation around May and June in Figure 3.1.d, and additionally not-bias-adjusted Model 3-1 differed from the observation in autumn. Model 3-2 and Model 4-2 have only bias-adjusted data. Despite Model 3-2 overestimated the observation means in May and June, in general, both models well correlated with the observation. Both bias-adjusted Model 3-3 and not-bias-adjusted Model 3-3 go almost parallel with the observation means through the whole year. While not-bias-adjusted Model 4-1 underestimated the observation in spring, autumn and winter, bias-adjusted Model 4-1 generally well correlated with the observation means with a slight overestimation from spring to autumn. According to visual inspections of Figure 3.1, Model 3-2 (HadGEM2-ES-*RACMO22E*), Model 3-3 (HadGEM2-ES-*RCA4*) and Model 4-2 (CM5A-MR-*WRF331F*) were able to emulate the daily precipitation in comparison to the observations.

Table 3.1 Root Mean Square Error (RMSE) and the Pearson's correlation coefficient (r) values of regionally averaged means of precipitation.

Model No	Daily Precipitation		Monthly Precipitation		Average Rank
	RMSE (mm)	r	RMSE (mm)	r	
1-1	8.89	0.04	49.71	0.54	6
2-1	8.85	0.06	48.93	0.60	3.5
2-2	9.18	0.05	49.58	0.56	6.75
3-1	8.95	0.04	44.48	0.61	2.25
3-2	8.78	0.05	44.82	0.61	<u>1.75</u>
3-3	9.06	0.05	46.89	0.58	4.25
4-1	9.22	0.03	53.01	0.49	7.25
4-2	8.70	0.04	47.23	0.58	4.25

Model statistics given in Table 3.1 shows that RCA4 models originated from different GCMs which are Model 2-2 (CNRM-CM5-*RCA4*), Model 3-3 (HadGEM2-ES-*RCA4*) and Model 4-1 (CM5A-MR-*RCA4*) have overestimated the mean daily precipitation as well as the mean monthly precipitation by having more RMSE values than others. Based on the average ranks, Model 3-2 (HadGEM2-ES-*RACMO22E*) and Model 4-1 (CM5A-MR-*RCA4*) have been determined as the best and worst models for mean daily precipitation, respectively.

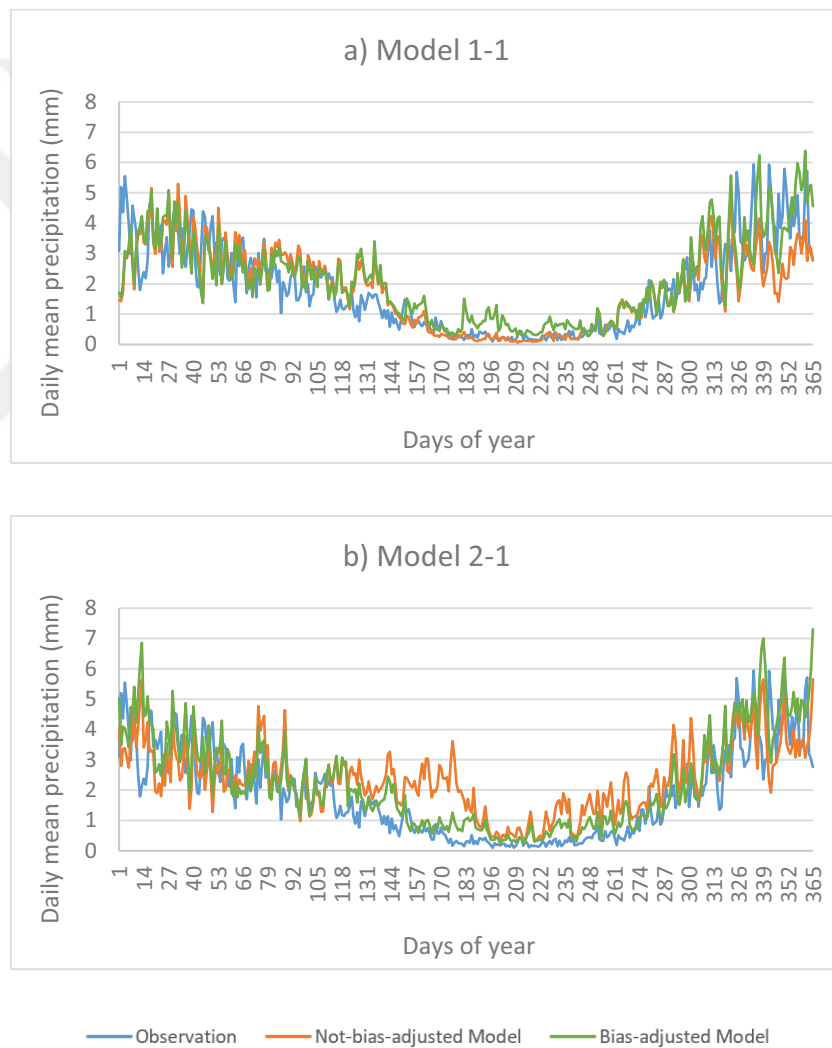
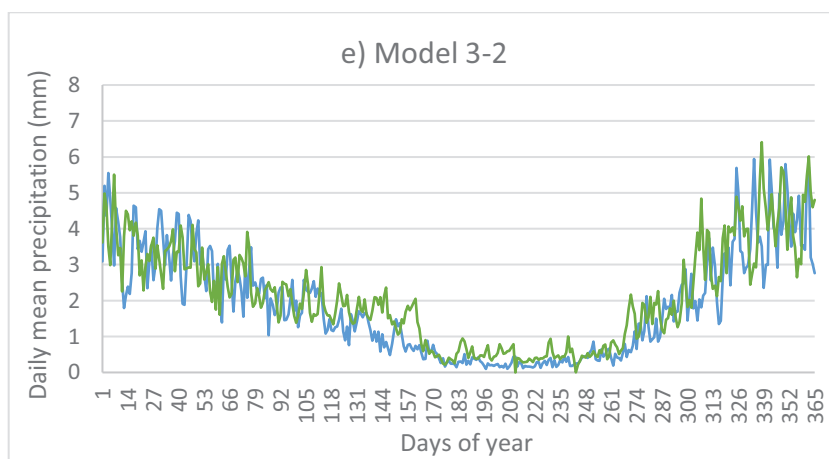
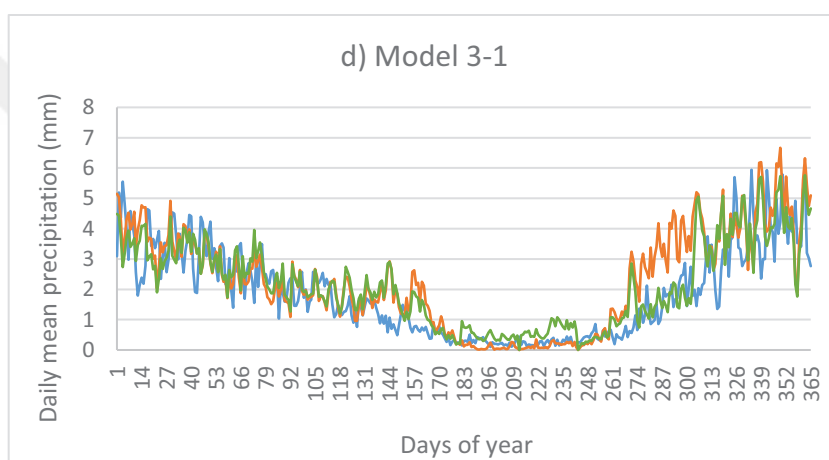
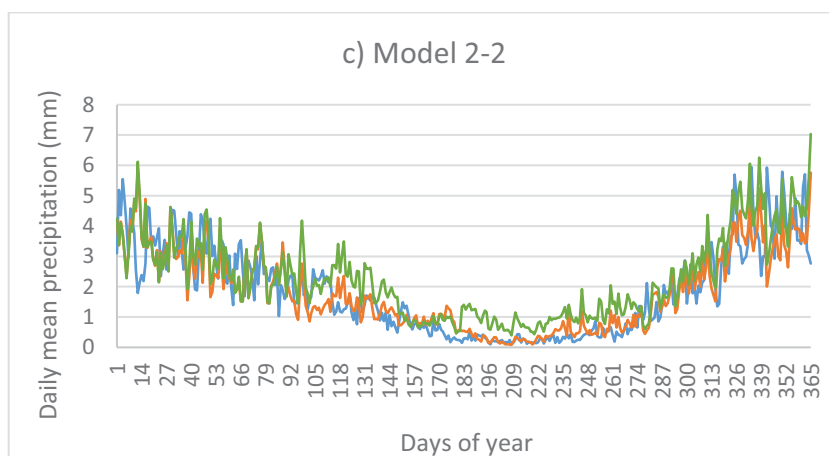
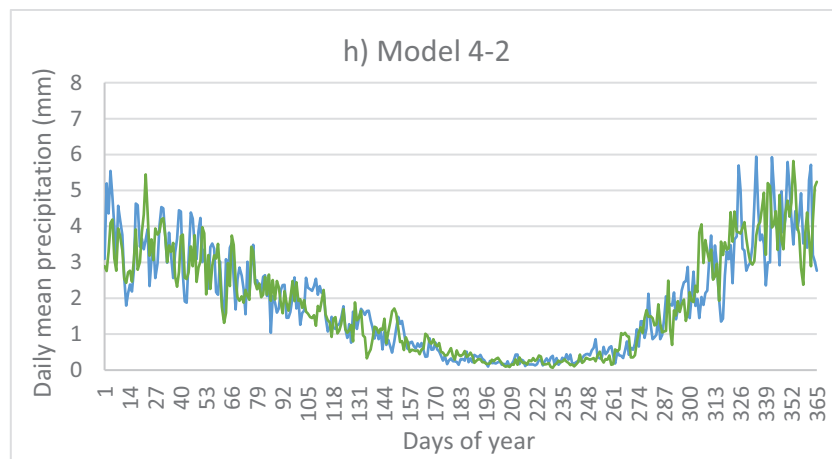
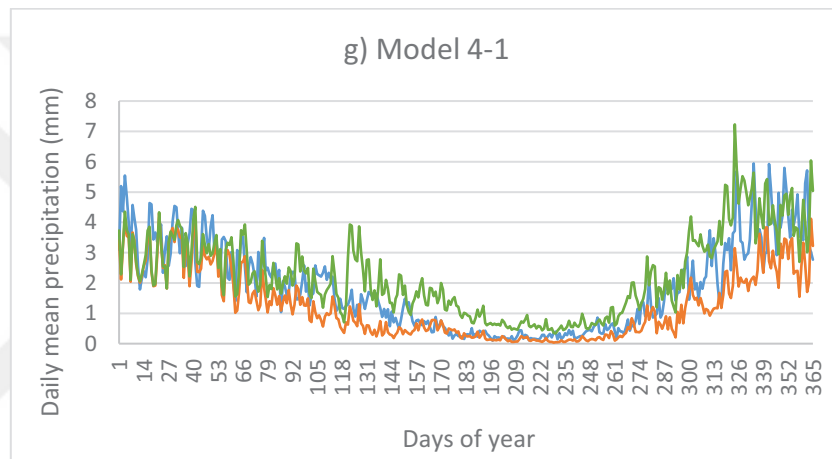
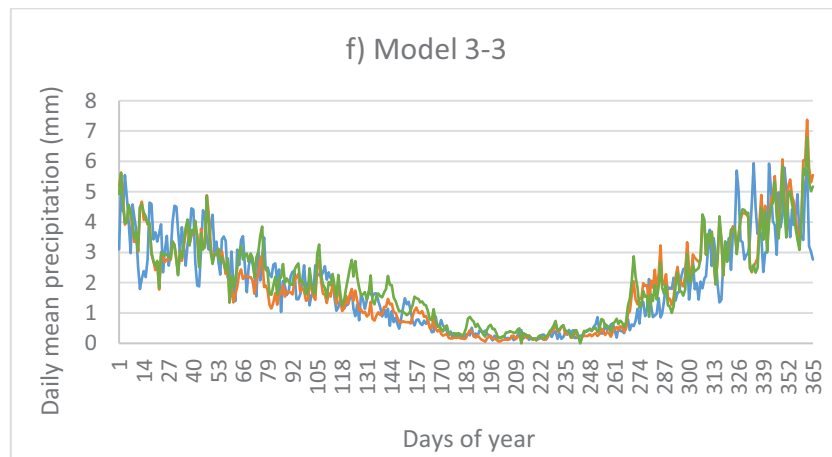


Figure 3.1. Regionally averaged daily mean precipitation of the region for the reference period 1971-2005.



— Observation — Not-bias-adjusted Model — Bias-adjusted Model

Figure 3.1. (cont'd)



— Observation — Not-bias-adjusted Model — Bias-adjusted Model

Figure 3.1. (cont'd)

3.1.2 Evaluation of Temperature Data

The same comparison with the precipitation has been made for the mean daily temperature. The plots in Figure 3.2 are for regionally averaged mean daily temperature for the reference period 1971-2005, and model data have been shown in different colors as not-bias-adjusted and bias-adjusted. According to visual examination of Figure 3.2, there are divergences between all not-bias-adjusted models and observation, estimated values have been below the observed values. In Figure 3.2, it can be seen that bias-adjusted models well correlated with the observation.

Table 3.2 Root Mean Square Error (RMSE) and the Pearson's correlation coefficient (r) values of regionally averaged means of temperature.

Model No	Daily Mean Temperature		Monthly Mean Temperature		Average Rank
	RMSE (°C)	r	RMSE (°C)	r	
1-1	5.96	0.81	1.98	0.97	4.75
2-1	5.93	0.81	1.93	0.96	3.75
2-2	5.93	0.81	1.85	0.97	2.63
3-1	6.57	0.76	2.12	0.96	6.38
3-2	6.53	0.77	2.16	0.96	6.75
3-3	6.56	0.76	2.15	0.96	6.75
4-1	5.87	0.81	1.95	0.97	2.75
4-2	5.82	0.81	1.88	0.97	2.25

Model statistics given in Table 3.2 shows that RCMs belong to HadGEM2-ES GCM which are Model 3-1 (HadGEM2-ES-*CCLM4-8-17*), Model 3-2 (HadGEM2-ES-*RACMO22E*) and Model 3-3 (HadGEM2-ES-*RCA4*) have overestimated the mean daily temperature as well as the mean monthly temperature by having more RMSE values than others. Based on the average ranks, Model 4-2 (CM5A-MR-*WRF331F*) has been determined as the best model while Model 3-3 (HadGEM2-ES-*RCA4*) as worst model for mean daily temperature, respectively. Thus, it can be concluded that the bias-adjusted models have approximated the estimated means to the actual values

better than the not-adjusted models. Therefore, bias-adjusted models shall be used in the analyses of precipitation and temperature.

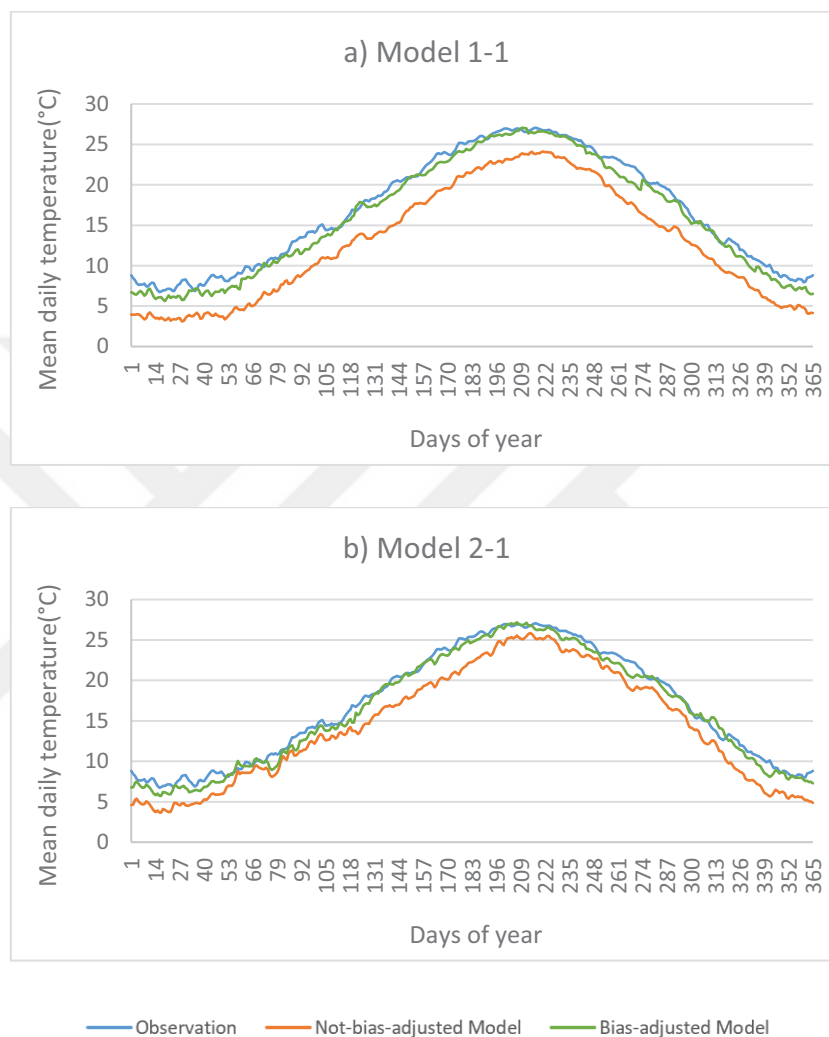
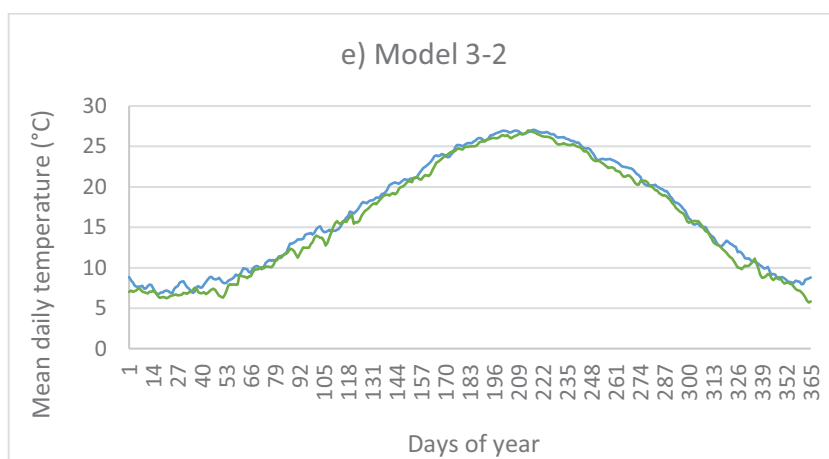
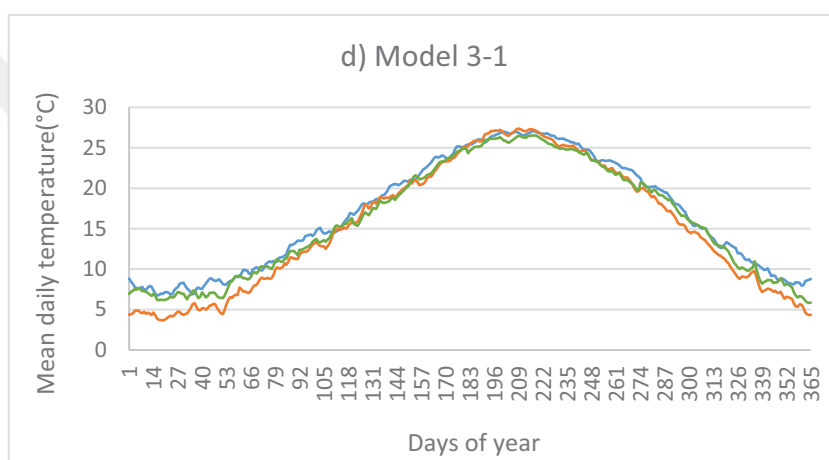
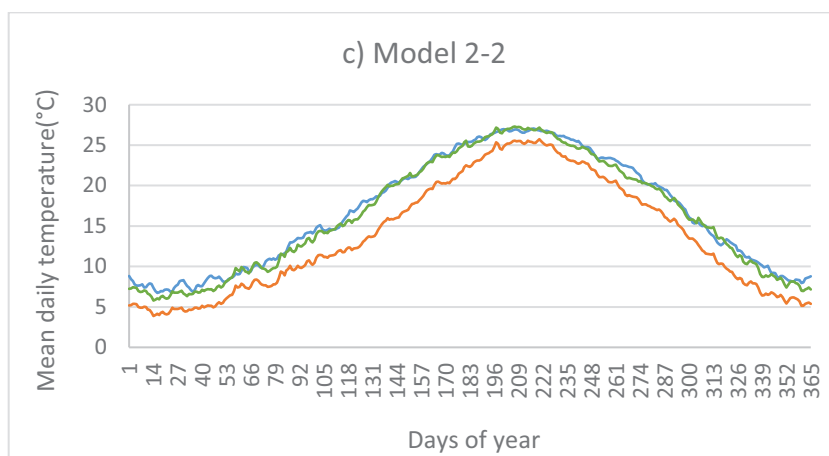
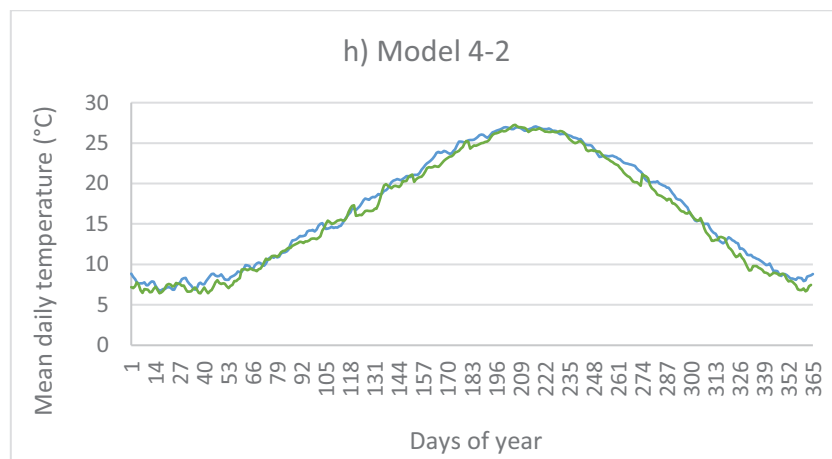
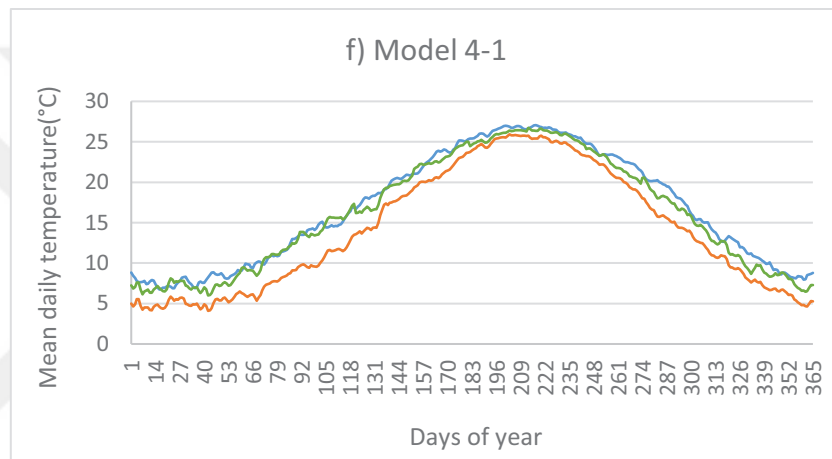
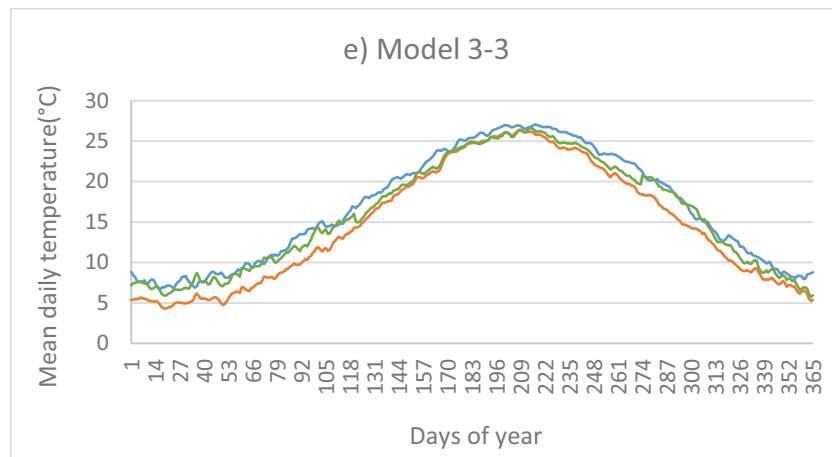


Figure 3.2. Regionally averaged mean daily temperature of the region for the reference period 1971-2005.



— Observation — Not-bias-adjusted Model — Bias-adjusted Model

Figure 3.2. (cont'd)



— Observation — Not-bias-adjusted Model — Bias-adjusted Model

Figure 3.2. (cont'd)

3.2 Spatial Distributions of Precipitation and Temperature

Seasonal and annual precipitation amount of the selected stations for the baseline period 1970-2011 has been given in the Table 3.3. Spatial distribution of the precipitation through the region has been shown in Figure 3.3 and Figure 3.4, as annual and seasonal respectively. Annually, maximum precipitation amounts have been observed in coastal regions mostly. However, high precipitation amount can be seen also at some stations in the interior part, such as Kozan and Karaisali stations (Figure 3.3.).

The region has received 46.9% of the total annual precipitation in winter season (Table 3.3). In autumn and winter season, the stations at coastal regions have measured higher values of precipitation. The southeastern part of the region has experienced wet season in spring in the baseline period. In summer season, 4.81% of the total annual amount of precipitation occurs in the region.

Table 3.3 Observed seasonal and annual precipitation amount of the selected stations in the baseline period (1970-2011).

Station	Precipitation (mm)					Station	Precipitation (mm)				
	MAM	JJA	SON	DJF	Annual		MAM	JJA	SON	DJF	Annual
Acipayam	124.94	42.36	102.49	225.98	500.65	Izmir	150.40	12.33	171.69	344.13	684.64
Adana	160.46	33.31	137.54	302.31	637.39	Kahramanmaraş	211.20	8.60	142.86	345.51	714.49
Akhisar	146.93	20.43	138.77	248.83	559.81	Karaisali	252.81	74.60	157.65	376.64	865.05
Anamur	161.18	5.45	218.21	522.67	915.44	Karaman	111.27	31.53	67.33	115.87	327.49
Antakya	331.18	32.77	223.87	494.13	1088.30	Karatas	141.66	23.02	206.21	393.99	770.30
Antalya	178.96	11.97	242.25	595.96	1042.98	Kilis	139.25	11.47	97.20	227.15	476.72
Aydin	156.75	19.54	140.25	294.35	618.02	Kocaeli	172.89	139.89	230.81	267.10	816.16
Ayvalik	141.62	14.10	173.94	297.78	633.40	Korkuteli	116.19	41.77	78.31	145.05	384.39
Balıkesir	149.30	33.25	150.90	215.45	554.34	Kozan	271.05	107.62	164.46	289.94	834.81
Bandırma	155.81	55.88	216.16	278.15	709.47	Kusadasi	136.83	7.05	154.65	303.57	610.28
Bodrum	126.68	6.11	151.21	388.57	683.93	Manavgat	169.11	12.93	282.46	626.26	1099.32
Burdur	135.44	48.53	89.72	142.31	417.05	Manisa	170.06	26.98	162.73	339.49	706.29
Bursa	176.90	68.37	198.43	245.48	695.38	Marmaris	202.69	17.53	275.35	673.45	1188.17
Canakkale	293.88	78.80	322.25	479.66	1184.43	Mersin	114.49	22.29	127.25	300.42	568.42
Ceyhan	209.41	39.52	146.32	310.11	707.59	Milas	156.14	17.86	157.81	355.49	696.50
Dalaman	169.25	7.58	241.21	541.80	971.52	Mugla	232.71	39.75	236.00	608.82	1127.39
Datca	110.92	4.96	152.21	376.48	654.30	Nazilli	143.78	24.95	129.72	277.12	577.88
Denizli	158.06	49.51	109.55	230.37	551.20	Nigde	124.54	35.26	70.69	97.79	329.59
Dikili	140.70	15.20	147.10	279.07	587.66	Odemiş	146.01	19.95	135.75	262.78	571.08
Dortyol	273.89	94.92	257.26	313.03	941.65	Salihli	131.98	32.68	114.57	204.67	487.47
Elmalı	113.76	46.31	95.58	216.51	476.27	Samandag	218.79	33.40	247.11	390.81	894.81
Erdemli	116.44	13.46	124.51	304.21	561.80	Seferihisar	132.48	5.20	144.40	318.08	601.70
Fethiye	153.11	5.52	201.83	453.62	822.23	Silifke	110.17	11.50	129.62	303.75	559.10
Finike	146.68	12.87	207.48	556.49	938.43	Tefenni	125.64	51.78	97.22	182.36	460.72
Gaziantep	161.31	12.11	112.74	263.16	551.78	Tekirdag	135.42	76.05	176.65	184.46	576.71
Gazipasa	157.23	5.10	229.91	434.72	832.49	Usak	156.96	50.34	122.83	197.00	531.63
İskenderun	197.18	62.48	204.96	257.24	723.93	Yatağan	152.60	30.74	143.97	310.56	645.49
İslahiye	227.86	10.26	159.25	406.25	808.14	Yumurtalik	204.00	37.14	210.45	354.19	810.16
Isparta	152.20	53.94	100.08	189.76	499.04						

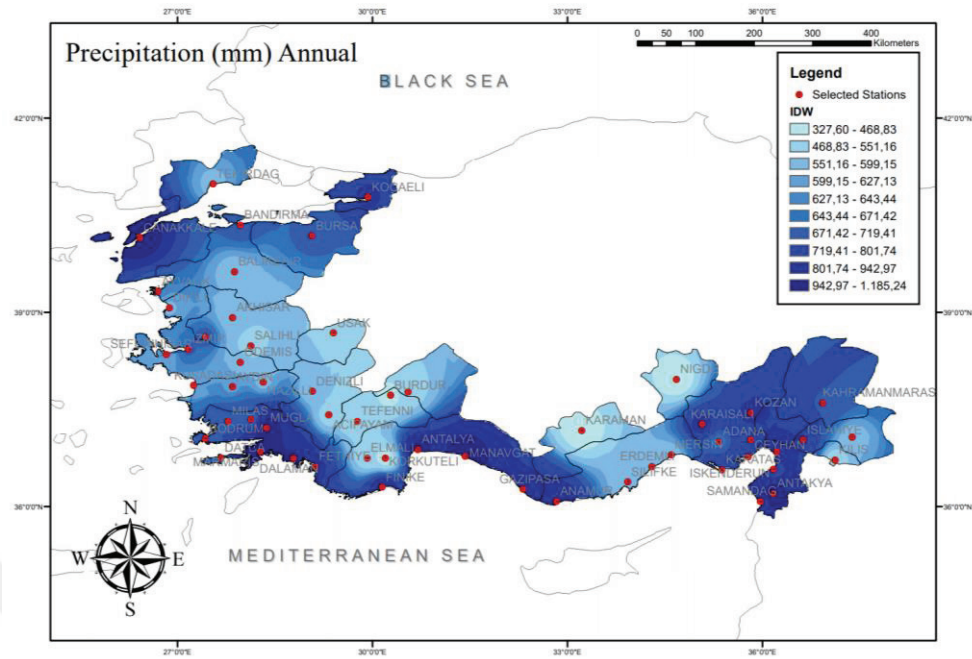


Figure 3.3. Annual precipitation distribution of the region in the baseline period (1970-2011).

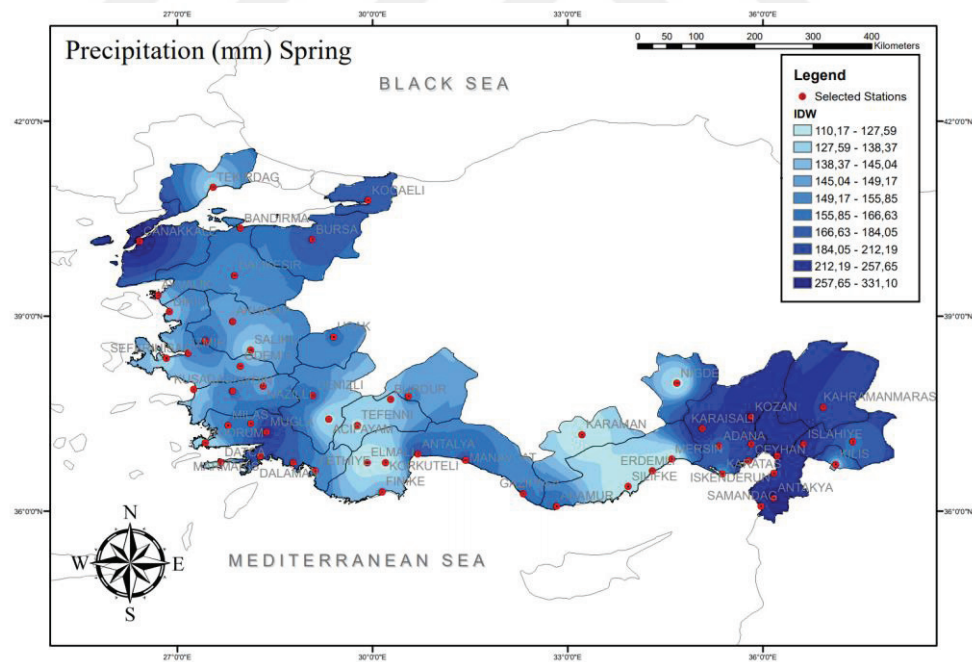


Figure 3.4. Seasonal precipitation distribution of the region in the baseline period (1970-2011).

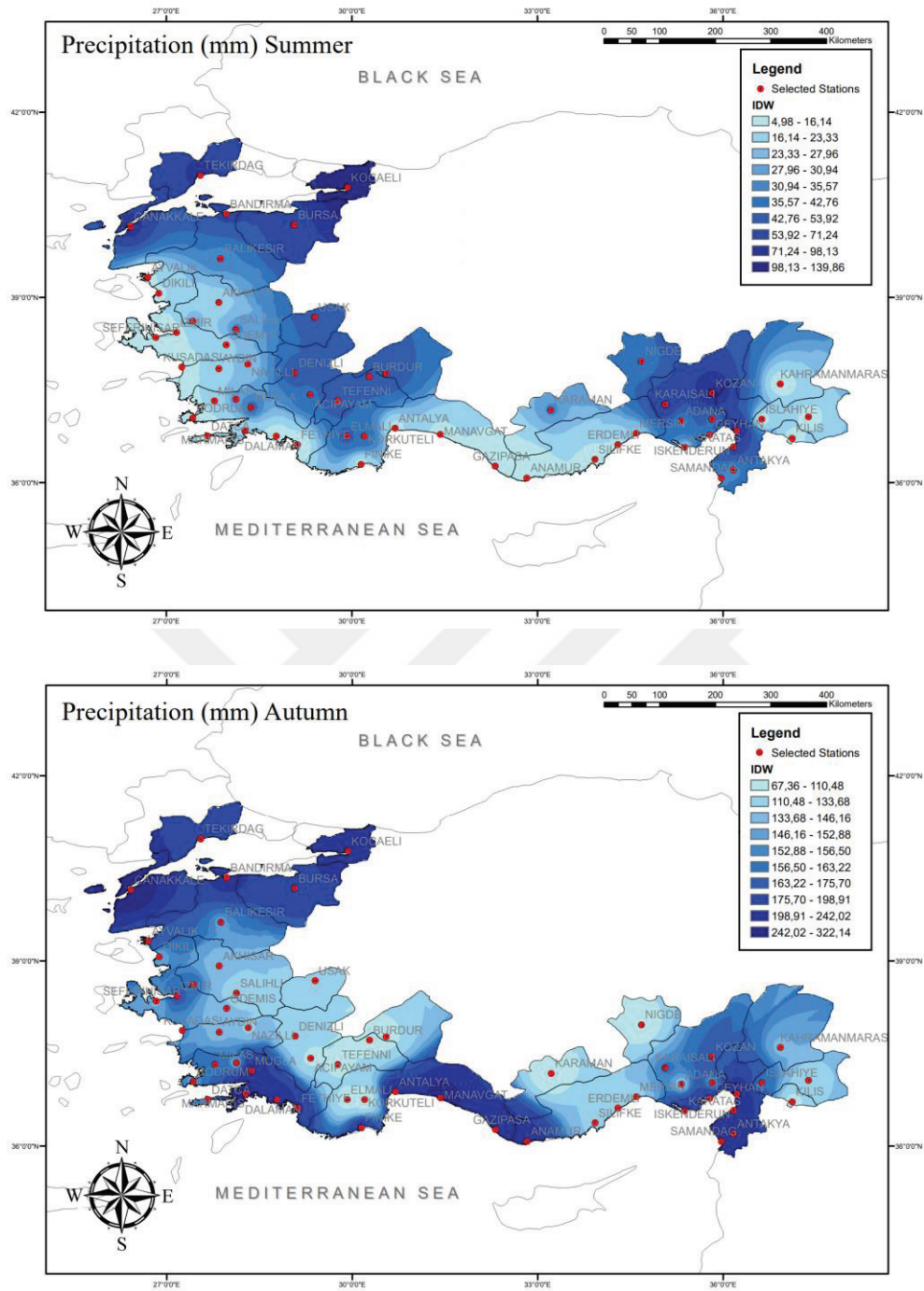


Figure 3.4. (cont'd)

On average, the region has received precipitation of 165.88 mm, 33.53 mm, 165.35 mm, 327.16 mm in spring, summer, autumn and winter, respectively.

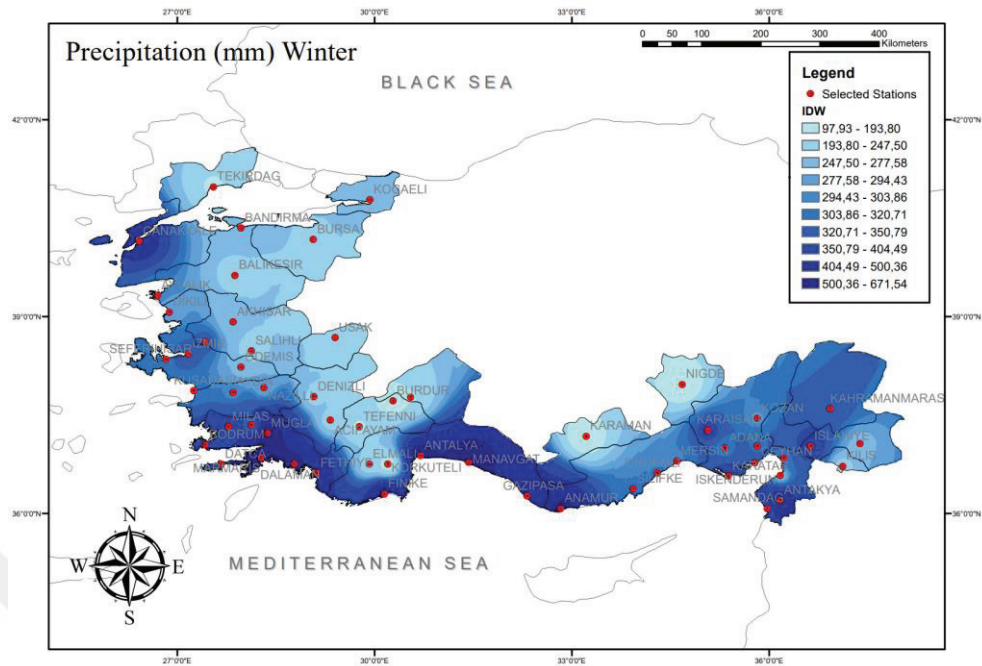


Figure 3.4. (cont'd)

Table 3.4 Observed seasonal and annual maximum temperature at the selected stations in the baseline period (1970-2011).

Station	Tmax (°C)					Station	Tmax (°C)				
	MAM	JJA	SON	DJF	Annual		MAM	JJA	SON	DJF	Annual
Acipayam	17.94	30.41	21.19	8.61	19.54	Izmir	21.18	32.36	23.77	13.30	22.65
Adana	23.85	33.29	28.09	16.02	25.31	Kahramanmaraş	21.20	34.36	25.13	10.37	22.76
Akhisar	21.64	33.83	24.19	12.12	22.95	Karaisali	22.13	33.16	26.86	14.22	24.09
Anamur	21.62	31.80	26.45	16.32	24.04	Karaman	17.78	29.95	20.29	6.38	18.61
Antakya	22.51	30.72	26.25	13.49	23.25	Karatas	21.31	29.57	25.97	15.50	23.09
Antalya	21.70	33.06	26.24	15.71	24.17	Kilis	21.47	34.86	25.51	10.85	23.17
Aydin	22.94	35.03	25.89	14.11	24.50	Kocaeli	18.05	28.47	20.38	10.39	19.32
Ayvalik	19.86	31.33	22.53	12.41	21.53	Korkuteli	17.65	29.47	21.24	9.30	19.41
Balikesir	19.13	30.33	21.54	9.86	20.23	Kozan	23.84	34.87	28.05	15.49	25.56
Bandirma	16.93	27.40	19.96	9.75	18.51	Kusadasi	20.36	30.04	22.98	14.25	21.91
Bodrum	21.56	33.12	25.36	15.64	23.92	Manavgat	21.92	32.51	26.45	15.82	24.17
Burdur	17.83	30.70	21.04	7.90	19.37	Manisa	21.45	34.11	23.87	11.65	22.78
Bursa	18.78	29.99	21.49	10.58	20.21	Marmaris	21.48	33.37	25.71	15.73	24.07
Canakkale	17.30	29.58	20.69	10.39	19.49	Mersin	21.54	30.06	26.06	15.66	23.33
Ceyhan	23.24	33.00	27.41	14.97	24.66	Milas	22.36	34.62	26.18	15.23	24.59
Dalaman	22.19	33.09	26.38	16.36	24.50	Mugla	19.15	32.23	22.85	10.82	21.26
Datca	20.21	31.29	24.46	15.34	22.82	Nazilli	20.92	34.30	27.92	13.88	24.23
Denizli	20.97	33.41	23.53	11.53	22.36	Nigde	16.41	28.13	19.24	5.79	17.39
Dikili	19.59	30.28	22.63	12.96	21.36	Odemis	21.83	33.84	24.97	13.51	23.54
Dortyol	22.50	30.70	26.68	16.04	23.98	Salihli	21.83	34.02	23.96	12.07	22.97
Elmalı	17.99	30.40	21.68	8.86	19.73	Samandag	21.65	29.21	25.79	14.70	22.84
Erdemli	21.78	30.50	26.36	15.84	23.62	Seferihisar	20.12	31.69	23.39	13.42	22.14
Fethiye	22.42	33.40	26.34	16.48	24.66	Silifke	22.86	32.21	27.05	15.53	24.41
Finike	22.15	33.07	26.55	16.65	24.60	Tefenni	17.11	29.40	20.07	7.38	18.49
Gaziantep	19.94	34.14	23.98	9.17	21.80	Tekirdag	15.78	27.06	19.41	9.16	17.85
Gazipasa	21.26	30.98	26.01	16.50	23.68	Usak	16.79	29.19	20.07	8.00	18.51
Iskenderun	22.21	30.18	26.38	16.21	23.75	Yatagan	21.14	33.97	24.74	12.61	23.11
Islahiye	21.21	33.57	25.35	10.34	22.68	Yumurtalik	21.82	30.15	26.83	15.95	23.69
Isparta	16.76	29.19	20.23	7.38	18.39						

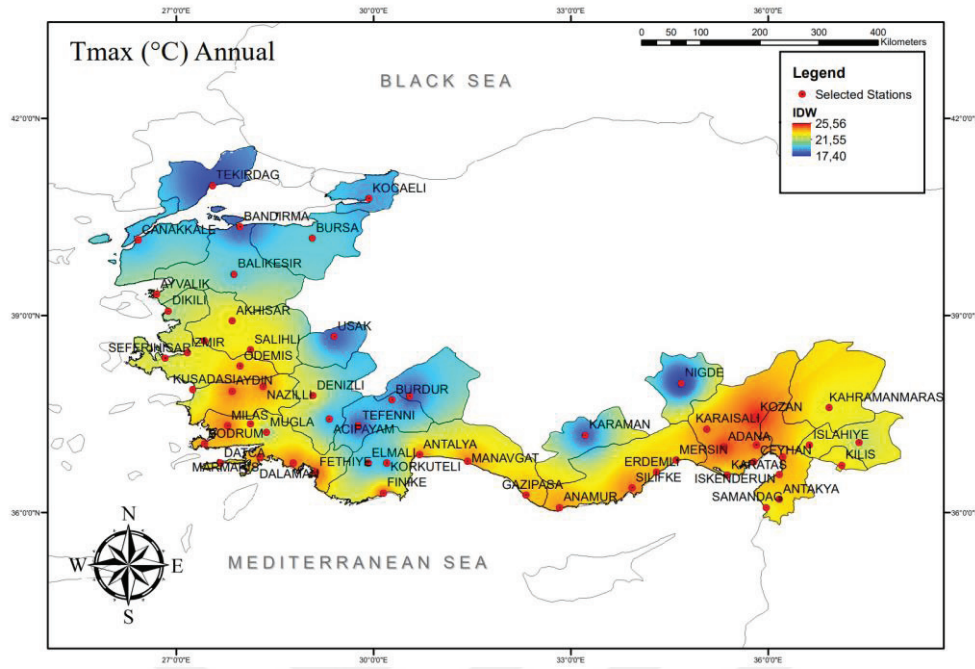


Figure 3.5. Annual maximum temperature distribution of the region in the baseline period (1970-2011).

The precipitation above the region average has been observed at the stations Kocaeli, Tekirdag, Bursa, Kozan, Karaisali and Ceyhan (Figure 3.4.).

Observed seasonal and annual averages of maximum temperature over the region in the baseline period have been given in the Table 3.4. According to the Figure 3.5., the region has experienced maximum 25.56°C temperature in annual average and the Aegean, the Mediterranean coast and the southeastern part of the study area have been warmer than interiors compared to the annual average. Interior parts of the region and the Marmara region had lower maximum temperature values in the baseline period. In the baseline period, summer seasons have been hot and winter seasons have been mild through the region. The highest average maximum temperature value has been observed at Aydin station in summer season and the lowest average value at Nigde station in winter season. In general, each season, the Aegean and the Mediterranean coast has experienced higher maximum temperature than region average while the interior parts and the Marmara region lower temperature (Figure 3.6.).

Table 3.5 shows observed seasonal and annual average minimum temperature values of the selected stations in the baseline period. As it can be seen in the Figure 3.7., average of minimum temperature has reached higher values through the coastal regions and lower values into the interior parts of the region. Similar behavior with maximum temperature can be seen in the seasonal state of minimum temperature, as well. As minimum temperatures observed at nights, it can be said that the stations Usak, Burdur, Tefenni, Acipayam, Fethiye, Elmalı, Karaman, Nigde and Kilis has experienced cooler nights than the other stations in every season. The highest average minimum temperature value -3.72°C has been observed at Nigde station in winter season and Samandag station had the lowest minimum temperature value of 24.23°C in summer season (Figure 3.8.).

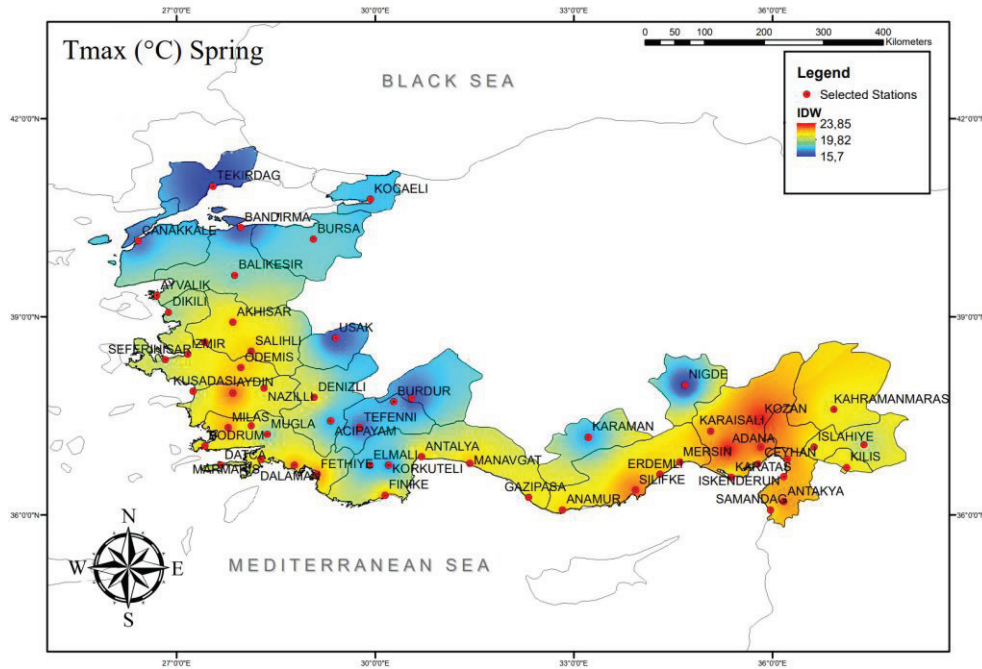


Figure 3.6. Seasonal maximum temperature distribution of the region in the baseline period (1970-2011).

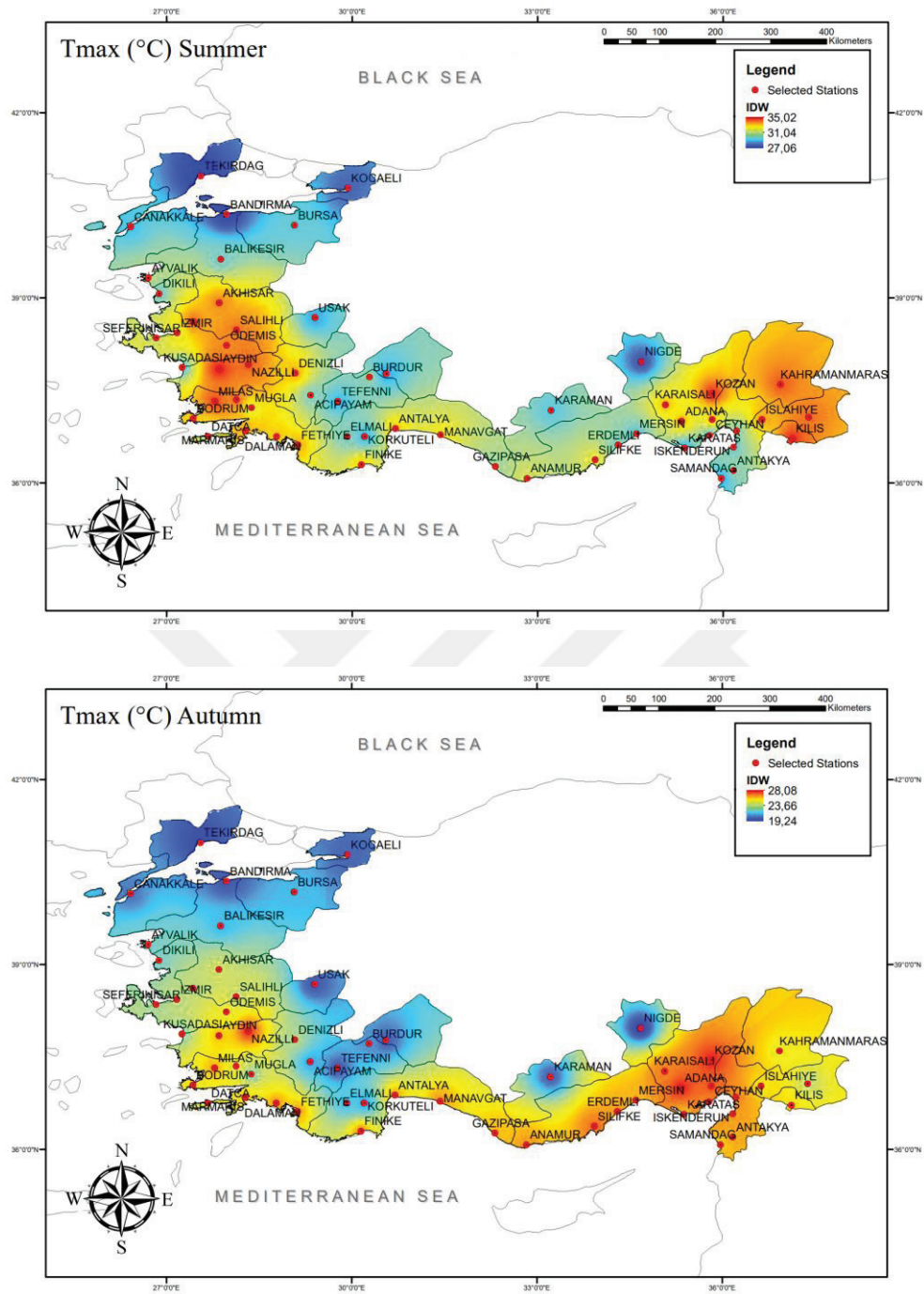


Figure 3.6. (cont'd)

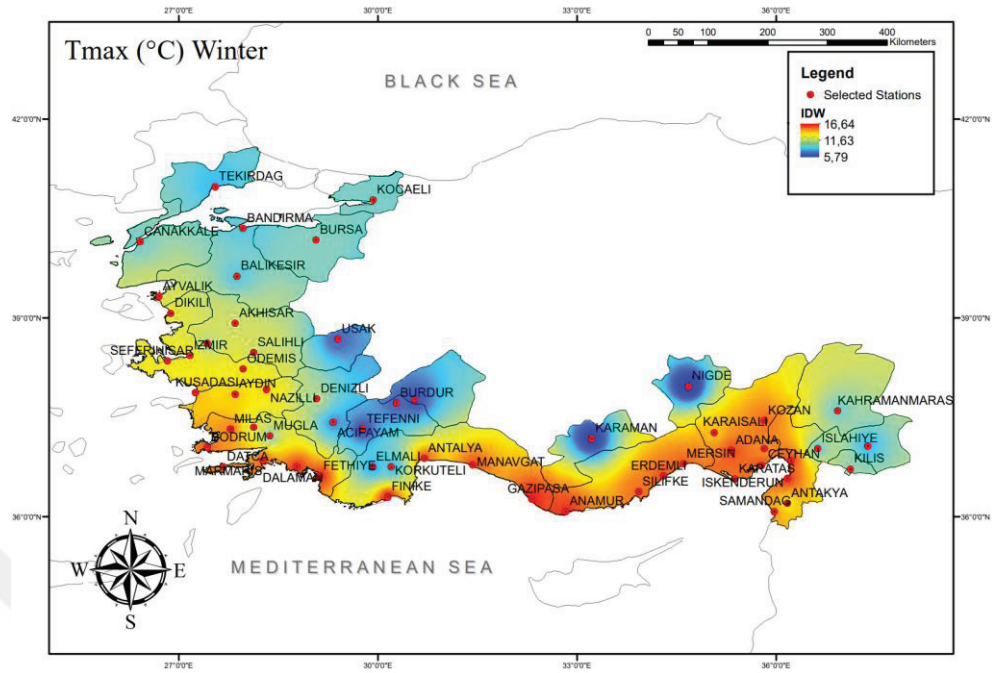


Figure 3.6. (cont'd)

Table 3.5 Observed seasonal and annual minimum temperature at the selected stations in the baseline period (1970-2011).

Station	Tmin (°C)					Station	Tmin (°C)				
	MAM	JJA	SON	DJF	Annual		MAM	JJA	SON	DJF	Annual
Acipayam	4.01	13.70	6.13	-1.85	5.50	Izmir	11.62	21.86	14.62	6.33	13.61
Adana	12.32	22.57	15.91	6.08	14.23	Kahramanmaraş	9.87	20.98	12.68	2.10	11.41
Akhisar	7.96	18.38	10.52	2.37	9.81	Karaisalı	11.93	21.38	15.95	6.31	13.90
Anamur	12.58	22.00	16.60	8.63	14.95	Karaman	4.54	14.09	5.56	-3.23	5.26
Antakya	12.35	23.05	15.24	5.17	13.96	Karatas	13.14	23.65	16.55	6.46	14.95
Antalya	11.40	21.62	14.94	6.51	13.61	Kilis	10.13	20.24	13.70	3.07	11.78
Aydin	10.36	19.70	12.65	4.89	11.90	Kocaeli	8.81	18.19	12.02	3.95	10.74
Ayvalik	10.25	20.36	13.36	5.17	12.29	Korkuteli	4.89	14.59	7.01	-1.26	6.31
Balikesir	7.12	16.93	9.89	1.89	8.97	Kozan	12.46	21.79	16.22	6.63	14.27
Bandirma	7.74	18.22	11.45	2.71	10.03	Kusadasi	10.52	19.30	13.11	6.08	12.25
Bodrum	12.98	22.46	16.59	8.73	15.19	Manavgat	11.55	21.11	15.46	7.46	13.89
Burdur	5.93	15.86	8.16	-0.43	7.39	Manisa	9.53	20.10	11.98	3.65	11.33
Bursa	7.36	16.60	9.74	2.28	9.00	Marmaris	11.83	22.04	15.64	7.47	14.25
Canakkale	8.84	18.85	12.07	3.97	10.93	Mersin	13.46	23.44	16.79	7.31	15.25
Ceyhan	10.20	20.34	13.02	3.69	11.82	Milas	9.33	19.43	12.34	5.23	11.58
Dalaman	10.02	19.68	13.28	6.06	12.26	Mugla	7.31	18.54	10.26	2.05	9.55
Dataca	13.43	22.97	17.96	10.13	16.12	Nazilli	9.45	19.19	11.35	3.79	10.94
Denizli	9.20	19.29	11.36	2.92	10.69	Nigde	4.39	13.86	5.88	-3.72	5.11
Dikili	10.26	19.86	13.18	5.06	12.09	Odemis	7.87	16.12	9.41	2.93	9.08
Dortyol	12.41	22.18	16.02	6.36	14.24	Salihli	8.88	18.02	10.38	2.87	10.04
Elmalı	5.23	15.17	7.59	-1.39	6.66	Samandag	13.72	24.23	17.62	7.28	15.72
Erdemli	11.00	21.72	14.60	5.71	13.26	Seferihisar	9.53	19.43	12.74	5.26	11.73
Fethiye	10.41	19.45	13.11	5.86	12.21	Silifke	12.90	22.29	16.94	7.74	14.97
Finike	11.37	20.26	14.84	7.62	13.52	Tefenni	4.17	13.74	6.33	-2.38	5.47
Gaziantep	7.60	19.72	7.87	-2.43	8.19	Tekirdag	8.24	18.21	11.70	2.84	10.25
Gazipasa	11.08	20.50	14.98	7.40	13.49	Usak	5.38	14.73	7.72	-0.48	6.84
Iskenderun	11.37	20.26	14.84	7.62	13.52	Yatagan	7.85	17.45	10.13	2.92	9.60
Islahiye	9.99	21.09	13.05	2.41	11.65	Yumurtalik	12.57	22.08	16.60	7.09	14.58
Isparta	4.47	13.83	5.98	-1.71	5.66						

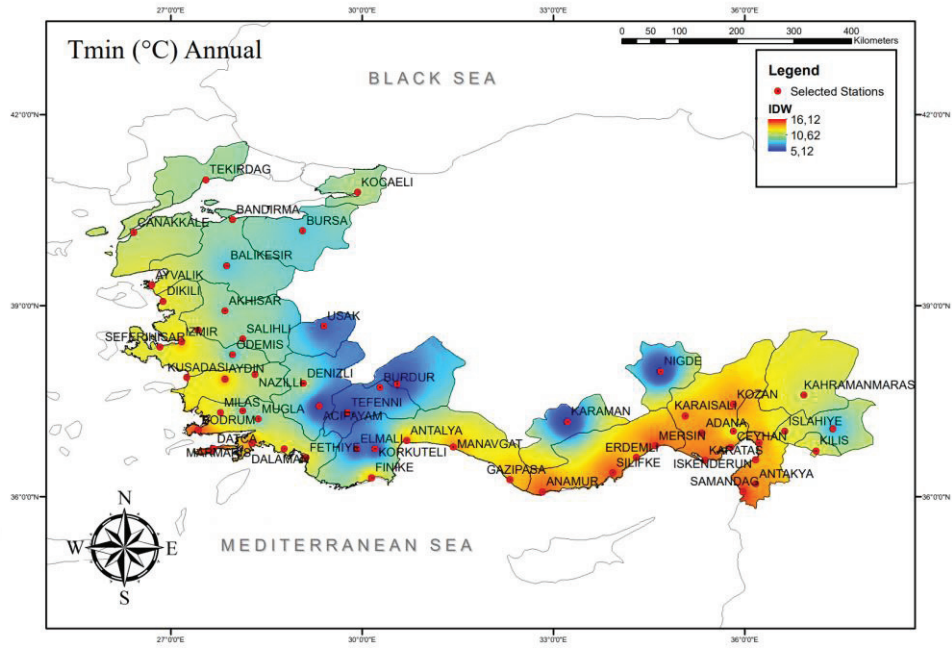


Figure 3.7. Annual minimum temperature distribution of the region in the baseline period (1970-2011).

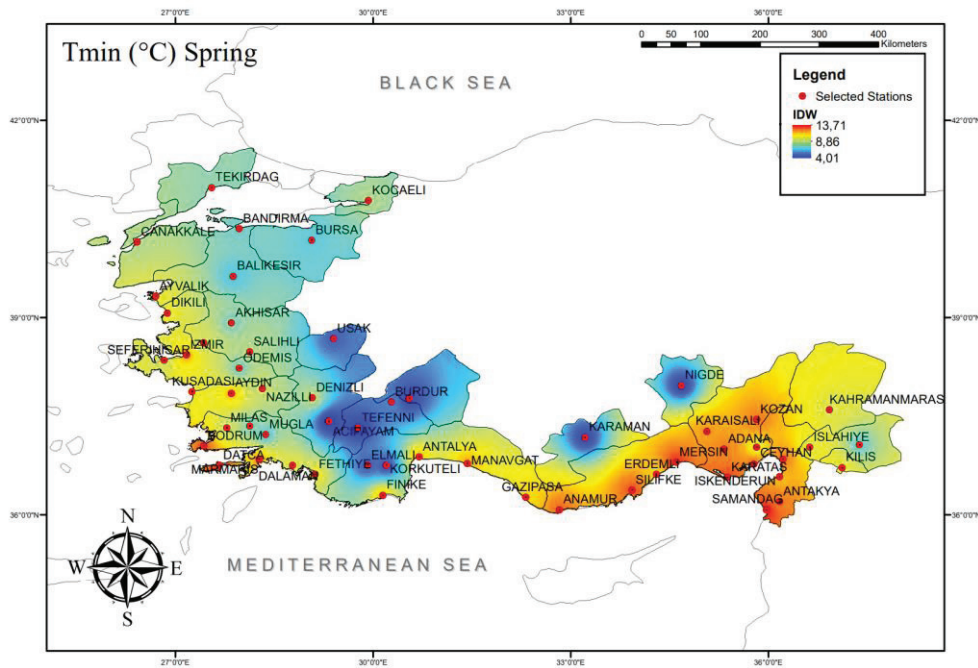


Figure 3.8. Seasonal minimum temperature distribution of the region in the baseline period (1970-2011).

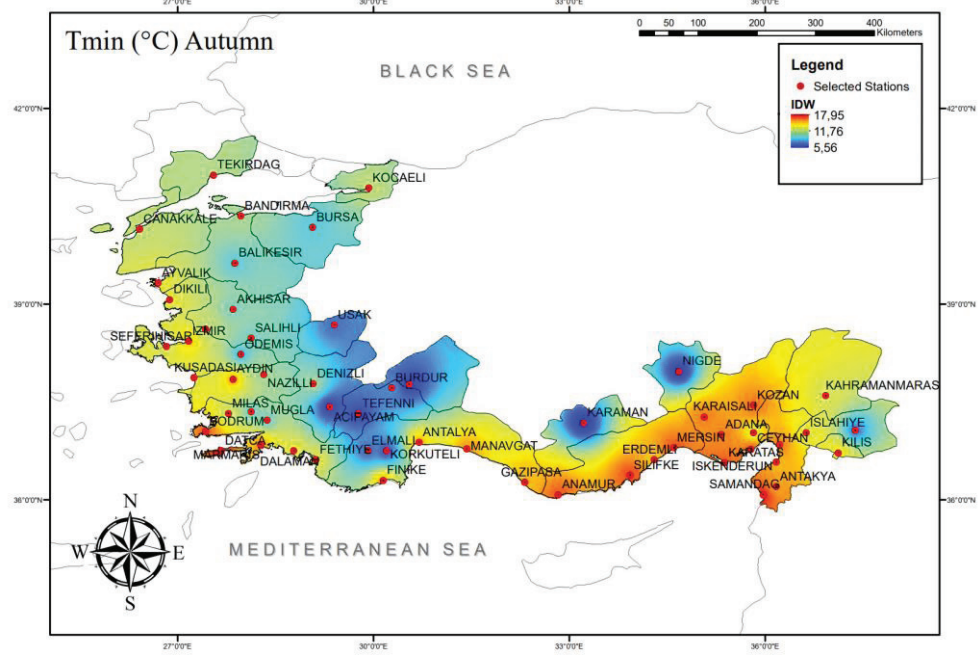
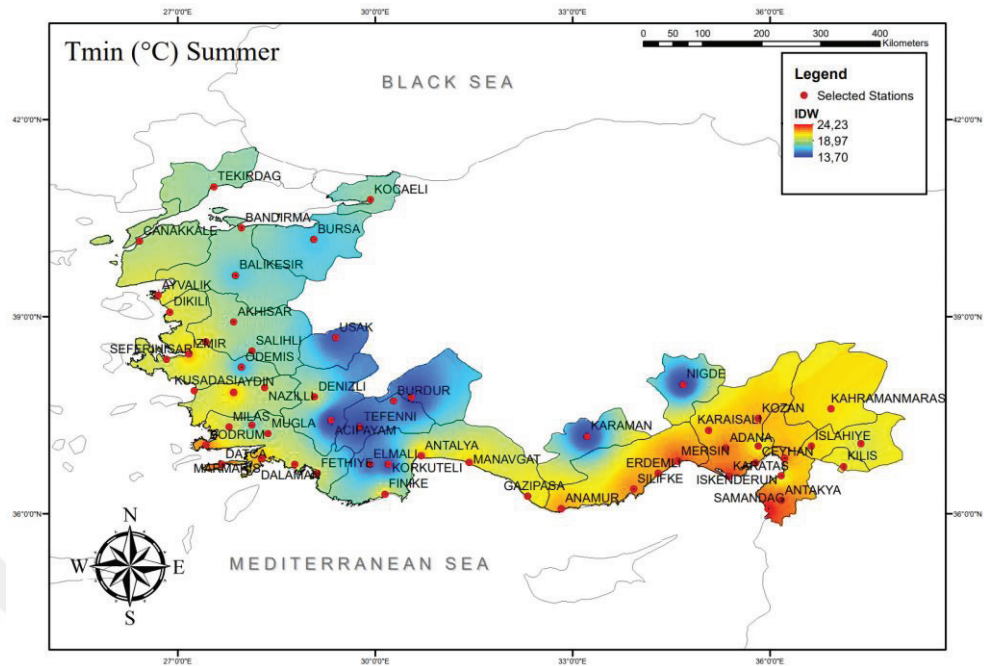


Figure 3.8. (cont'd)

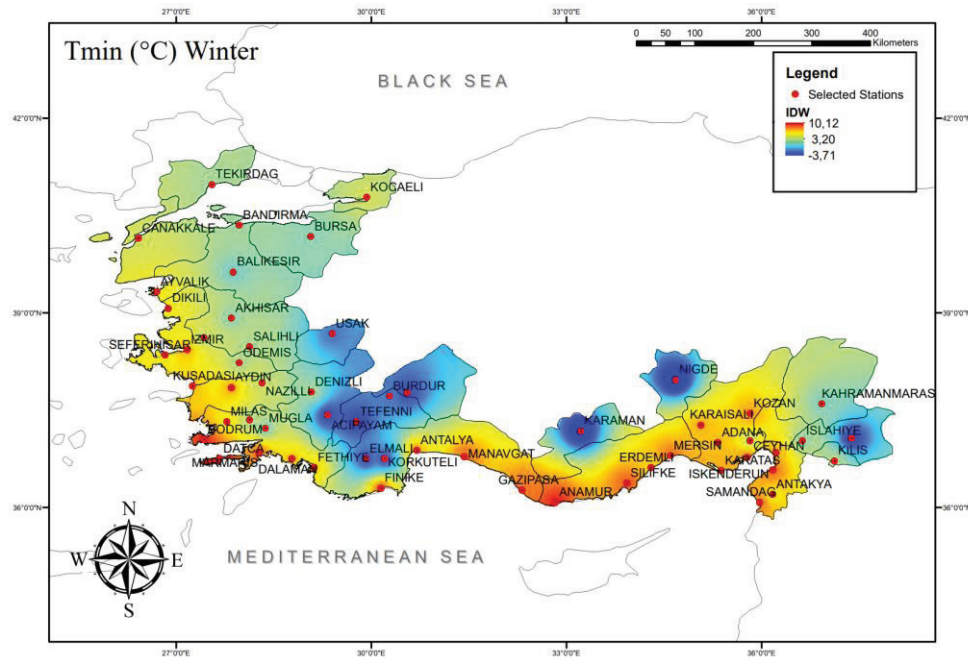


Figure 3.8. (cont'd)

3.3 Trends in Precipitation and Temperature

3.3.1 Annual Trends

The results of the trend test and the values of Sen's slope for precipitation and temperature have been shown in Table 3.6. Z values above 1.96 indicate the significant trend at 5% level while Sen Slope values represent the magnitude. A mixed pattern has been observed in precipitation trends but there is no significant trend detected in precipitation in the baseline period except for the significant positive trend in Burdur station with 2.188 mm. In general, maximum and minimum temperature have significant positive trend with the averages of 0.03°C and 0.04°C, respectively through the region. There is non-significant positive trend and non-significant negative trend in temperatures of some stations, but those are negligible for baseline period and need to be checked for future projections. Spatial distributions of the results have been shown in Figure 3.9.

Table 3.6 Annual trend (Z) and Sen's slope of the precipitation, maximum and minimum temperatures at the stations in the baseline period. Significant values had shown by bold and underlined font.

Station	Precipitation		Tmax		Tmin		Station	Precipitation		Tmax		Tmin	
	Z	Sen Slope	Z	Sen Slope	Z	Sen Slope		Z	Sen Slope	Z	Sen Slope	Z	Sen Slope
Acipayam	1.29	2.249	<u>4.64</u>	0.052	<u>5.66</u>	0.062	Izmir	0.15	0.464	<u>2.53</u>	0.032	<u>2.91</u>	0.023
Adana	0.09	0.292	0.09	0.001	<u>2.60</u>	0.013	Kahramanmaraş	1.58	3.289	<u>2.15</u>	0.037	<u>2.64</u>	0.035
Akhisar	-0.46	-1.275	<u>4.12</u>	0.03	<u>5.43</u>	0.053	Karaisalı	-0.44	-0.967	1.02	0.008	1.63	0.012
Anamur	-0.15	-0.362	<u>4.12</u>	0.025	<u>6.50</u>	0.066	Karaman	-1.18	-1.178	<u>2.67</u>	0.029	<u>2.53</u>	0.025
Antakya	0.61	1.575	<u>2.35</u>	0.03	<u>2.71</u>	0.043	Karatas	0.35	1.03	<u>2.98</u>	0.02	<u>4.28</u>	0.036
Antalya	0	-0.047	1.11	0.021	<u>2.17</u>	0.06	Kilis	-1.2	-1.64	1.48	0.012	<u>2.35</u>	0.042
Aydin	0.47	0.906	<u>2.30</u>	0.04	<u>4.56</u>	0.039	Kocaeli	0.72	1.175	<u>2.11</u>	0.022	1.05	0.008
Ayvalik	-0.06	-0.193	<u>3.45</u>	0.024	<u>4.21</u>	0.032	Korkuteli	1.09	1.199	<u>3.54</u>	0.032	<u>2.24</u>	0.017
Balıkesir	-0.14	-0.182	<u>2.23</u>	0.03	-0.97	-0.011	Kozan	0.12	0.25	-1.67	-0.014	<u>5.58</u>	0.06
Bandırma	-0.1	-0.183	-0.06	-0.0002	<u>4.30</u>	0.037	Kusadasi	0.66	1.282	<u>4.37</u>	0.03	<u>7.06</u>	0.1
Bodrum	-0.3	-0.73	<u>5.81</u>	0.049	<u>4.01</u>	0.039	Manavgat	1.2	4.079	<u>2.46</u>	0.018	<u>3.49</u>	0.026
Burdur	<u>2.12</u>	2.188	<u>2.15</u>	0.038	0.44	0.003	Manisa	-1.52	-3.473	<u>3.46</u>	0.03	<u>3.00</u>	0.039
Bursa	0.13	0.19	<u>2.03</u>	0.028	<u>2.46</u>	0.027	Marmaris	0.48	2.051	<u>2.82</u>	0.022	<u>5.45</u>	0.052
Canakkale	0.33	0.686	1.24	0.012	<u>2.28</u>	0.039	Mersin	0.61	1.417	<u>2.12</u>	0.051	1.65	0.092
Ceyhan	1.63	3.642	-0.08	-0.002	<u>3.94</u>	0.054	Milas	-0.19	-0.833	<u>4.64</u>	0.046	<u>6.64</u>	0.072
Dalaman	-0.39	-1.552	<u>3.22</u>	0.041	1.2	0.009	Mugla	-0.33	-1.242	<u>2.17</u>	0.045	<u>2.89</u>	0.021
Datca	0.98	2.012	<u>5.34</u>	0.044	<u>2.64</u>	0.014	Nazilli	0.57	0.966	<u>2.46</u>	0.024	1.67	0.013
Denizli	0.85	1.255	<u>2.15</u>	0.044	<u>2.33</u>	0.065	Nigde	1.18	2.371	<u>3.44</u>	0.039	<u>2.80</u>	0.039
Dikili	-0.55	-1.18	<u>2.12</u>	0.017	<u>3.81</u>	0.033	Odemiş	-0.1	-0.361	1.9	0.015	<u>3.61</u>	0.033
Dortyol	1.74	5.051	<u>4.17</u>	0.031	<u>4.21</u>	0.031	Salihli	0.06	0.061	<u>4.53</u>	0.035	<u>5.07</u>	0.05
Elmalı	0.8	1.343	<u>3.83</u>	0.035	<u>4.95</u>	0.032	Samandag	1.18	3.532	<u>2.95</u>	0.021	<u>3.38</u>	0.024
Erdemli	-0.26	-0.532	<u>3.92</u>	0.028	<u>3.34</u>	0.023	Seferihisar	1.36	3.07	<u>3.88</u>	0.045	<u>5.25</u>	0.051
Fethiye	0.93	2.444	<u>4.48</u>	0.037	<u>6.44</u>	0.087	Silifke	-0.12	-0.326	<u>3.79</u>	0.033	<u>3.65</u>	0.029
Finike	0.95	3.955	<u>3.58</u>	0.029	<u>7.49</u>	0.091	Tefenni	0.64	0.961	<u>4.41</u>	0.044	<u>3.85</u>	0.034
Gaziantep	0.85	1.422	<u>2.94</u>	0.032	<u>4.90</u>	0.056	Tekirdag	1.16	1.886	<u>2.44</u>	0.031	1.85	0.027
Gazipasa	0.72	2.067	<u>4.14</u>	0.026	<u>2.24</u>	0.014	Usak	1.04	1.513	<u>2.66</u>	0.03	<u>3.45</u>	0.026
Iskenderun	1.83	2.458	<u>5.00</u>	0.044	<u>7.49</u>	0.091	Yatagan	0.26	0.721	<u>5.74</u>	0.062	1.58	0.009
Islahiye	-0.03	-0.275	<u>2.83</u>	0.033	<u>3.25</u>	0.025	Yumurtalik	1.067	3.121	<u>5.20</u>	0.043	<u>4.30</u>	0.042
Isparta	0.54	0.993	<u>2.55</u>	0.032	<u>2.93</u>	0.05							

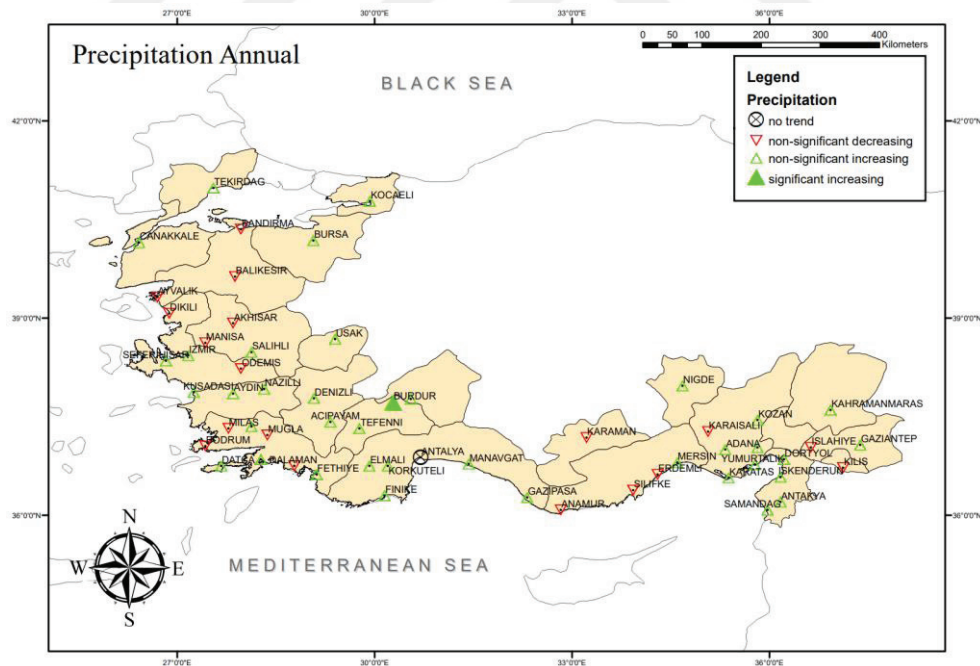


Figure 3.9. Spatial distributions of annual trends in precipitation, maximum and minimum temperature of the region in the baseline period (1970-2011).

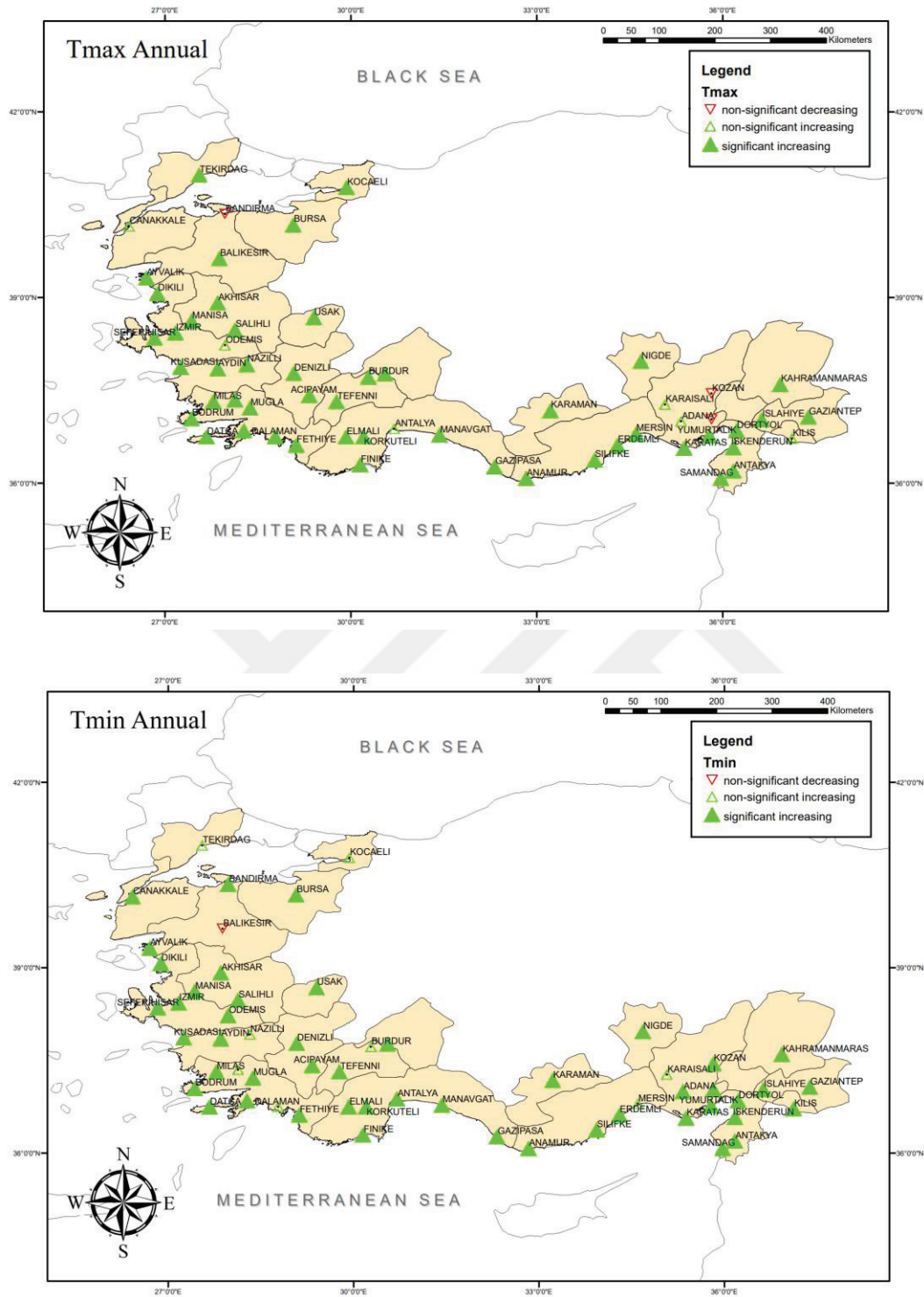


Figure 3.9. (cont'd)

3.3.2 Seasonal Trends

Seasonal trends of precipitation and temperature of the stations in the baseline period 1970-2011 have been presented in Table 3.7. All trend values within the thesis have been checked at 5% significance level. Spatial distributions of seasonal trends in precipitation and temperature in the baseline period can be found in Appendix A.

There have been differences observed in the precipitation trends among the seasons in the baseline period. Mostly decreasing trend has been found in seasons spring, summer and winter, while increasing trend in autumn. Almost whole trends in precipitation is non-significant in this region for this period but some stations have showed significant trends in different seasons. Ayvalik station in spring, 5 stations (Bandirma, Bodrum, Milas, Odemis and Salihli) in summer had significant decreasing trend. 4 stations (Elmali, Gaziantep, Korkuteli and Nigde) had significant

Table 3.7 Seasonal trends of precipitation, maximum and minimum temperatures at the stations in the baseline period 1971-2011. Significance is specified at the 5% level. +, -, s+, s- and nt indicate positive, negative, significant positive, significant negative and no trend, respectively.

Station	Precipitation				Tmax				Tmin				Station	Precipitation				Tmax				Tmin			
	MAM	JJA	SON	DIF	MAM	JJA	SON	DIF	MAM	JJA	SON	DIF		MAM	JJA	SON	DIF	MAM	JJA	SON	DIF	MAM	JJA	SON	DIF
Acipayam	+	nt	+	-	s+	s+	s+	s+	s+	s+	s+	s+	Izmir	-	-	+	-	+	s+	s+	s+	+	s+	s+	+
Adana	+	-	+	-	+	+	-	+	-	s+	+	+	Kahramanmaraş	+	-	+	+	+	s+	+	+	s+	+	s+	+
Akhisar	-	-	+	-	+	s+	+	+	s+	s+	s+	+	Karaisalı	-	-	+	-	+	+	-	+	-	s+	+	+
Anamur	-	-	+	-	s+	s+	s+	s+	s+	s+	s+	s+	Karaman	-	-	+	-	+	s+	+	+	+	s+	s+	+
Antakya	+	-	+	+	s+	s+	+	+	s+	s+	s+	+	Karatas	-	-	+	+	s+	s+	s+	+	s+	s+	s+	+
Antalya	+	-	-	-	+	+	+	+	s+	+	s+	s+	Kilis	-	+	+	-	+	s+	-	+	s+	s+	s+	s+
Aydin	+	-	+	-	s+	s+	+	s+	s+	s+	s+	s+	Kocaeli	+	-	+	+	+	s+	+	+	-	+	+	+
Ayvalik	s-	+	nt	nt	+	s+	+	s+	+	s+	s+	s+	Korkuteli	-	+	s+	-	+	s+	+	+	s+	+	+	+
Balıkesir	-	-	+	-	+	s+	+	+	s-	+	s-	-	Kozan	-	+	+	-	-	-	s-	+	s+	s+	s+	s+
Bandirma	-	s-	+	+	+	+	-	s+	s+	s+	s+	+	Kusadasi	-	-	+	+	s+	s+	s+	s+	s+	s+	s+	s+
Bodrum	-	s-	+	-	s+	s+	s+	s+	s+	s+	s+	s+	Manavgat	+	-	+	+	+	s+	+	+	s+	s+	+	+
Burdur	+	+	+	-	+	s+	s+	+	-	s+	-	+	Manisa	-	-	-	-	+	s+	s+	+	+	+	s+	+
Bursa	-	-	+	+	+	s+	+	+	+	s+	s+	+	Marmaris	+	-	+	+	+	s+	+	+	s+	s+	s+	s+
Canakkale	-	-	+	+	+	s+	+	+	s+	s+	s+	+	Mersin	-	+	+	+	s+	s+	s+	s+	s+	+	s+	+
Ceyhan	-	-	+	+	-	+	-	+	+	s+	s+	s+	Milas	-	s-	+	-	s+	s+	s+	s+	s+	+	s+	s+
Dalaman	+	-	-	-	+	s+	s+	s+	-	s+	s+	+	Mugla	+	-	+	-	s+	s+	+	s+	+	s+	+	+
Datca	-	-	+	+	s+	s+	s+	s+	+	s+	s+	+	Nazilli	+	-	+	-	+	s+	s+	+	-	s+	+	-
Denizli	+	-	+	-	+	s+	s+	s+	s+	s+	s+	s+	Nigde	+	+	s+	+	s+	s+	+	s+	s+	s+	s+	+
Dikili	-	+	+	-	+	s+	+	+	+	s+	s+	+	Odemis	-	s-	+	-	+	s+	+	+	+	s+	s+	s+
Dortyol	-	+	+	-	s+	s+	s+	s+	s+	s+	s+	+	Salihli	-	s-	+	-	+	s+	+	s+	+	s+	s+	+
Elmali	+	+	s+	-	s+	s+	+	s+	+	s+	s+	s+	Samandag	-	-	+	+	+	s+	+	+	s+	s+	+	+
Erdemli	-	-	+	-	s+	s+	s+	+	+	s+	s+	+	Seferihisar	-	-	+	+	+	s+	s+	s+	s+	s+	s+	s+
Fethiye	+	-	+	+	s+	s+	s+	s+	s+	s+	s+	s+	Silifke	-	-	+	-	s+	s+	s+	s+	s+	s+	s+	+
Finike	-	nt	+	+	s+	s+	s+	s+	s+	s+	s+	s+	Tefenni	+	-	+	-	+	s+	+	s+	s+	s+	s+	+
Gaziantep	-	+	s+	+	+	s+	+	s+	s+	s+	s+	+	Tekirdag	-	-	+	+	+	s+	s+	+	+	s+	s+	+
Gazipasa	-	-	+	+	s+	s+	s+	s+	+	s+	+	+	Usak	+	+	+	-	+	s+	s+	s+	+	s+	s+	+
Iskenderun	+	+	+	+	s+	s+	s+	s+	s+	s+	s+	s+	Yatagan	+	-	+	-	s+	s+	s+	s+	-	s+	+	+
Islahiye	-	+	+	-	+	s+	+	+	+	s+	s+	+	Yumurtalik	-	-	+	+	s+	s+	s+	s+	s+	s+	s+	s+
Isparta	+	+	+	-	+	s+	s+	s+	s+	s+	s+	+													

positive trend in autumn and there have been no significant trends in winter. In summer any trend has not been observed at Acipayam and Finike stations while Ayvalik station has no trend in winter. (Table 3.7. and Appendix A.).

Maximum temperature trend in the region has increased for all seasons in the baseline period. In spring season, at 32 stations non-significant and 23 stations significant positive trend have been observed. Significant positive trends have placed, especially, through the South Aegean and Mediterranean coasts. 2 stations (Ceyhan and Kozan) have showed non-significant negative trend in spring season, while only 1 station (Kozan) in summer season and 5 stations (Adana, Bandirma, Ceyhan, Karaisali and Kilis) in autumn season. There have been 1 significant negative trend observed at Kozan station in autumn season. In wintertime, no negative trend has been found through the region in the baseline period (Table 3.7).

There has been dominantly increasing trend in minimum temperature of the region in the baseline period. Among all seasons, only 1 station, which is Balikesir station, have showed significant decreasing trend in terms of minimum temperature in spring and autumn seasons. Besides, non-significant decreasing trend has been observed at 7 stations (Adana, Burdur, Dalaman, Karaisali, Kocaeli, Nazilli and Yatagan) in spring, at 1 station (Burdur) in autumn and at 3 stations (Balikesir, Gazipasa and Nazilli) in winter (Table 3.7).

In brief, precipitation trends have decreased in spring, summer and winter seasons, while summer precipitation trends have increased. Both maximum and minimum temperatures have showed significant increasing trend with slight decreasing exceptions. Non-significant trend values have been checked with future projection in the following parts of the thesis.

3.4 Trends of Climate Indices

3.4.1 Annual Trends

The number of stations with positive, negative and no annual trend in the baseline period has been given in Table 3.8. and annual trend values of climate indices of the stations in the baseline period in the Table 3.9. The significant trends for each index have been specified at the 5% level (values with linear trend value less than 0.05 were determined) and highlighted with blue color in the Table 3.8.

According to those tables, 10 temperature-related indices (SU25, TR, GSL, TXx, TNn, TNx, TXn, WSDI, TX90, TN90) have had a positive trend at most stations and only 3 of them (GSL, TNn, TXn) is non-significant. Other temperature indices (FD,

Table 3.8 The number of stations with positive and negative annual trends in the baseline period 1970-2011. +, -, s+, s-, nt indicate non-significant positive, non-significant negative, significant positive, significant negative, no trend, respectively.

Indices	+	-	s+	s-	nt	Indices	+	-	s+	s-	nt
FD	10	37	2	8	0	TX10	1	15	0	41	0
ID	10	16	0	0	31	TX90	5	1	50	1	0
SU25	11	3	43	0	0	TN10	0	8	1	48	0
TR	3	0	54	0	0	TN90	6	0	51	0	0
GSL	35	20	2	0	0	CDD	27	27	0	2	1
TXx	23	5	29	0	0	CWD	32	23	0	0	2
TNn	32	15	10	0	0	R20mm	41	15	1	0	0
TNx	11	0	46	0	0	Rx5day	35	11	10	1	0
TXn	33	11	9	0	4	PRCPTOT	38	17	2	0	0
DTR	11	16	8	21	1	R95p	39	13	5	0	0
WSDI	28	2	27	0	0	R95pTOT	39	12	6	0	0
CSDI	8	32	0	17	0						

DTR, CSDI, TX10, TN10) have had a negative trend mostly and trends of DTR, TX10, TX90 are significant, while ID index had a no trend. Non-significant positive trend has been observed in all precipitation indices (CWD, R20mm, Rx5day, PRCPTOT, R95p, R95pTOT) except CDD index. CDD index in 27 stations had a positive trend and in 29 stations had a negative trend that 2 of them is significant.

As it can be seen in Figure 3.10., amount of cool days (TX10) and amount of cold nights (TN10) trends at almost each station are significant negative. TN10 trend is significant positive at only Balıkesir station. Amount of hot days (TX90) and amount of hot nights (TN90) had increased over the study area in the baseline period. Only Kozan station had a significant negative trend in TX90 index. Warmest daily minimum temperature (TNx) and warmest daily maximum temperature (TXx) had been rising significantly at most stations in the baseline period. Coldest daily minimum temperature (TNn) and coldest daily maximum temperature (TXn) trends had relatively mixed pattern, but mostly positive trend has been observed in TNn and TXn indices in the baseline period (Figure 3.11.). In Figure 3.12., it has been shown that annual number of days when $TX > 25^{\circ}\text{C}$ (SU25) and annual number of days when $TN > 20^{\circ}\text{C}$ (TR20) had significant increasing trend mostly. Annual number of days when $TN < 0^{\circ}\text{C}$ (FD, frost days) had negative trend at most part of the study area. Annual number of days when $TX < 0^{\circ}\text{C}$ (ID, ice days) indicator had mostly no trend in the region, especially over the coastal regions. Warm spell duration index (WSDI) has increased significantly. In contrast, cold spell duration index (CSDI) had decreasing trend over the study area even if most of it is not significant. Growing season length (GSL) indicator had positive trend at most stations in the baseline period. Daily temperature range (DTR) has reduced over the region mostly (Figure 3.13). Intensity indicators, which are PRCPTOT (annual sum of daily precipitation ≥ 1.0 mm), Rx5day (maximum 5-day precipitation total), R20mm (annual number of days when precipitation ≥ 20 mm), R95p (annual sum of daily precipitation $> 95^{\text{th}}$ percentile), had positive trend at most stations although there is a mixed pattern over the study area (Figure 3.14.). Spatial distributions of the other precipitation indices (CDD, CWD, R95pTOT) has been shown in Figure 3.15. According to this figure, the number of stations with positive trend in CWD (maximum annual number of consecutive wet days (when precipitation ≥ 1.0 mm)) and R95pTOT (contribution from very wet days) indicators is more than the number of stations with negative trend.

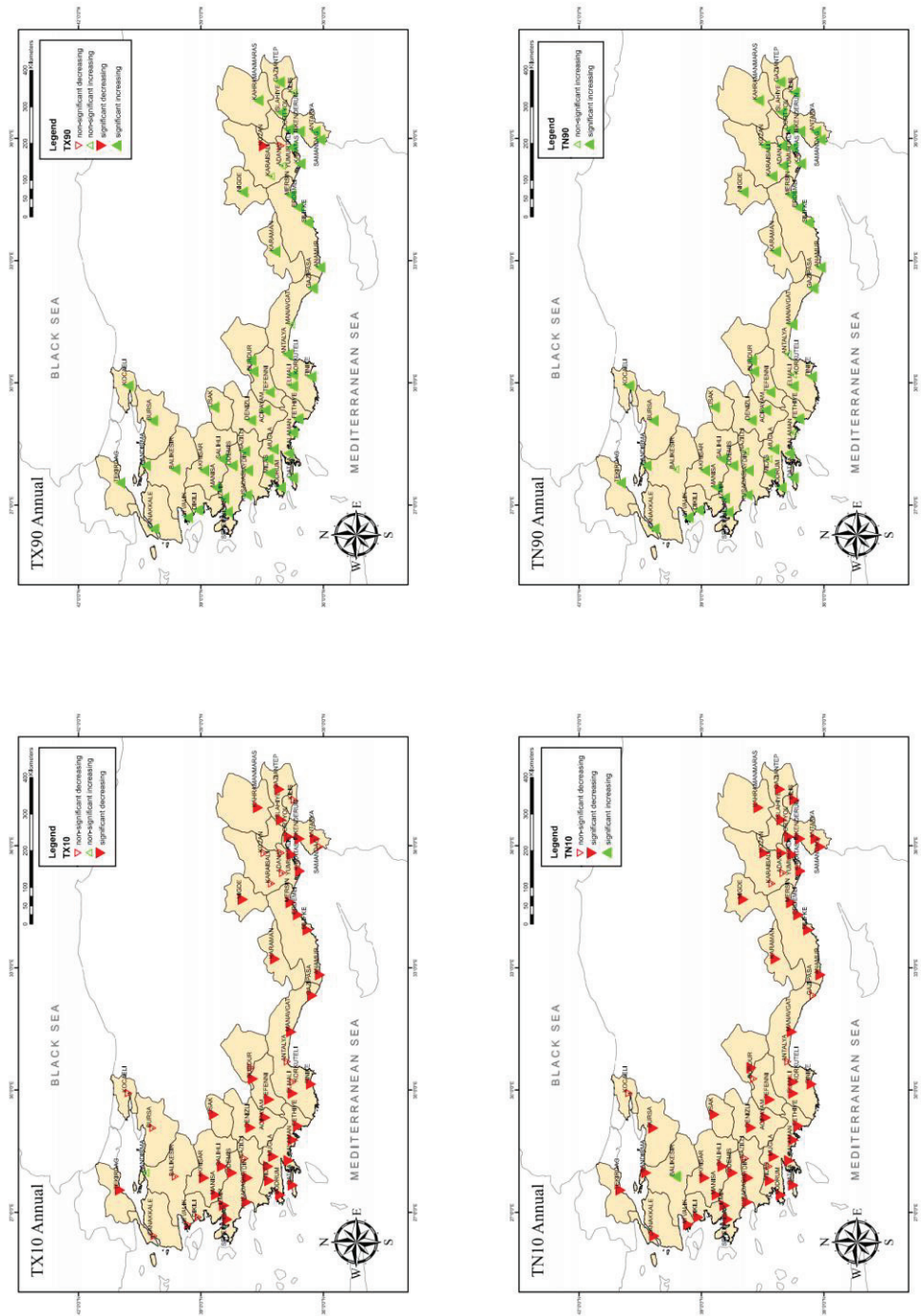


Figure 3.10. Annual trends of percentile-based indicators (TX10, TX90, TN10, TN90) in the baseline period 1970-2011.

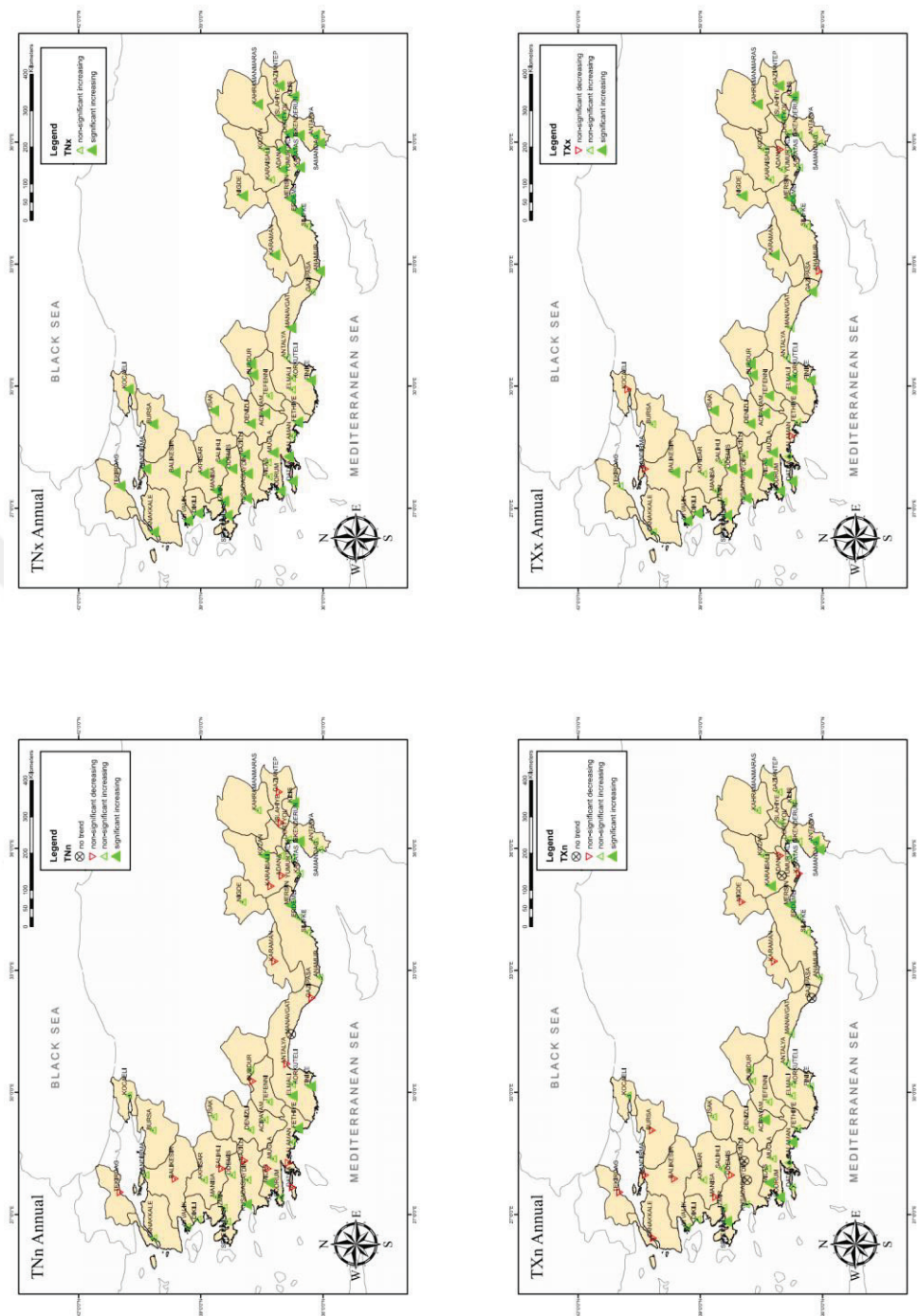


Figure 3.11. Annual trends of absolute indicators (TNN, TNx, TXn, TXx) in the baseline period 1970-2011.

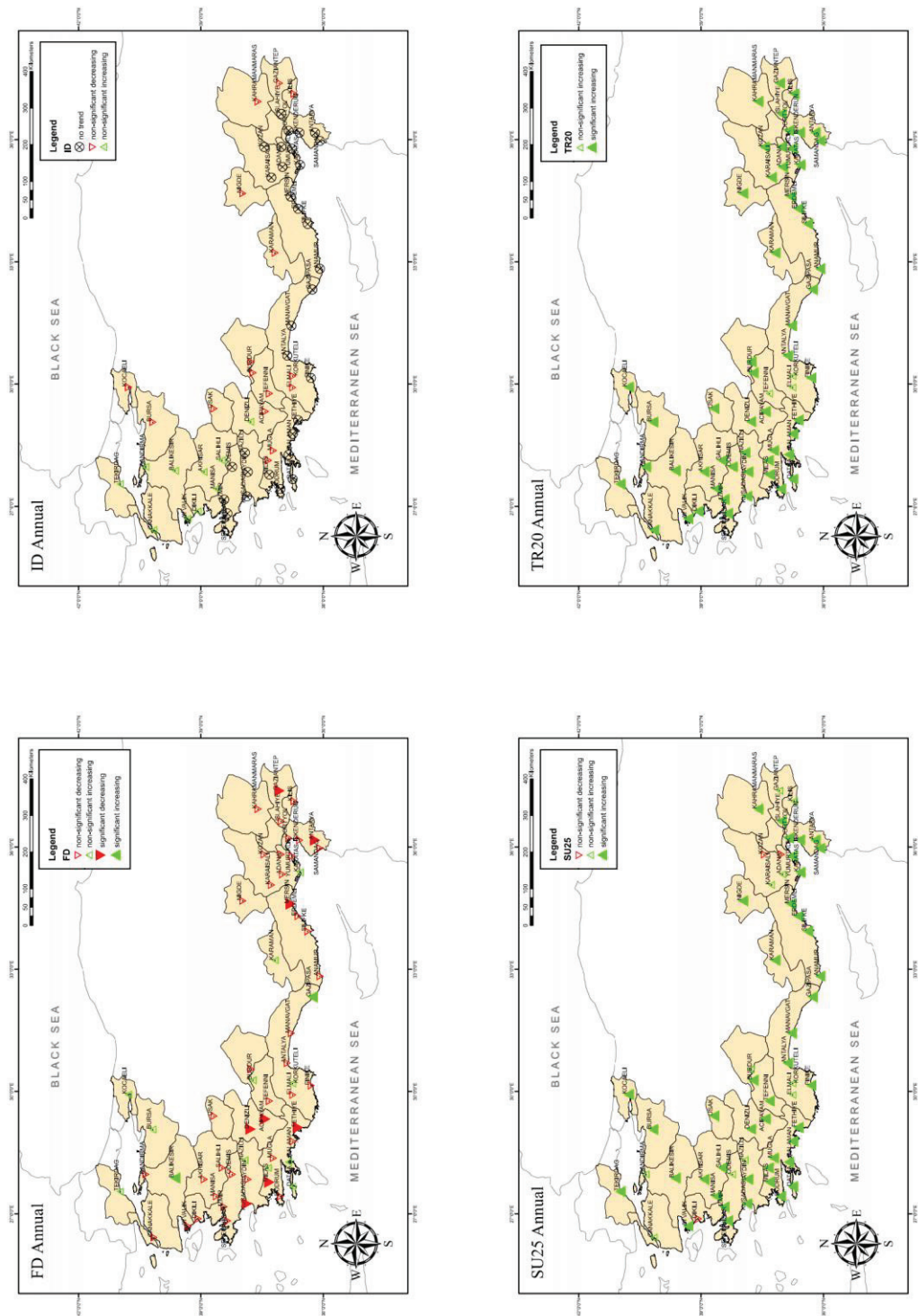


Figure 3.12. Annual trends of threshold indicators (FD, ID, SU25, TR20) in the baseline period 1970-2011

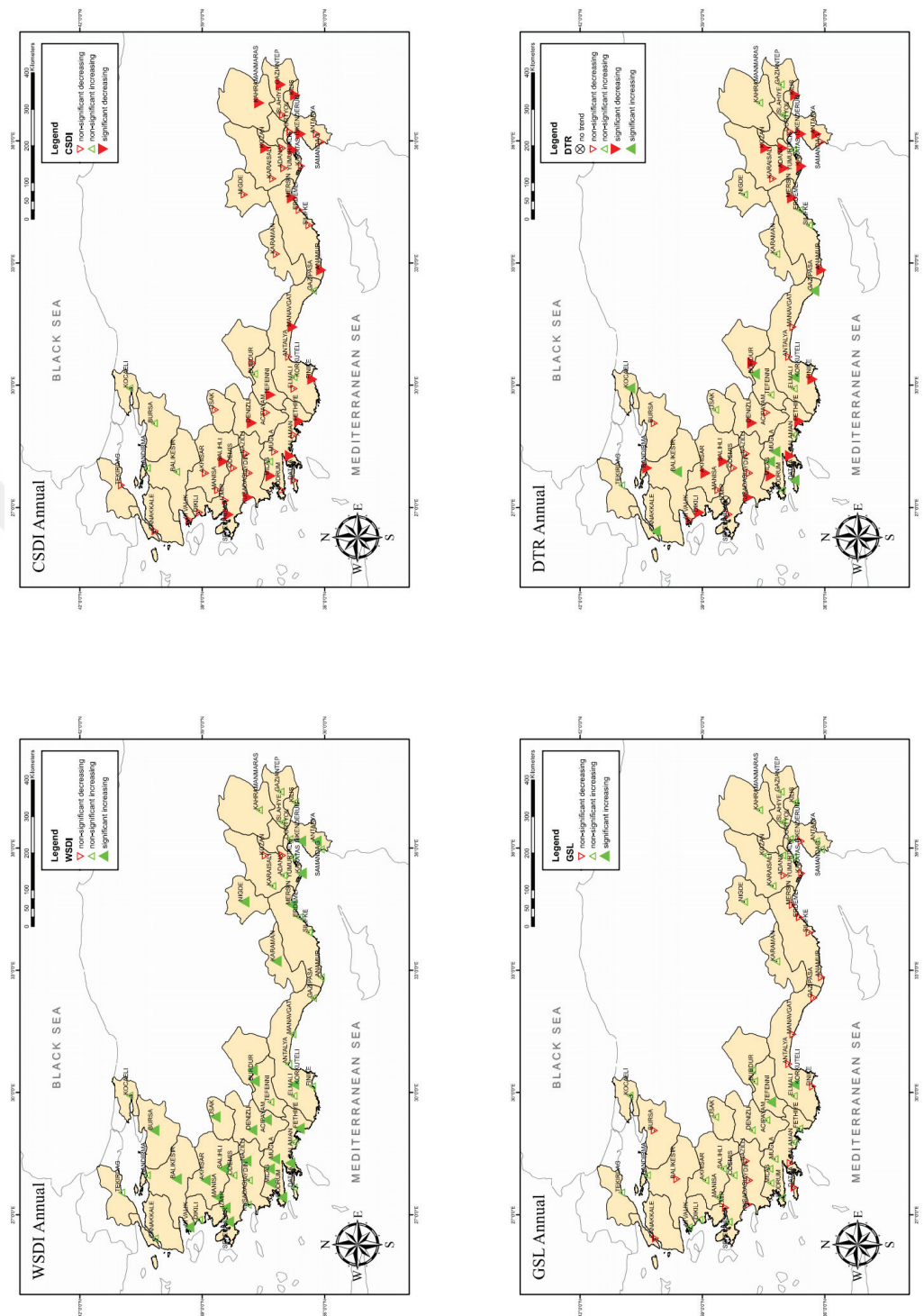


Figure 3.13. Annual trends of duration indicators (WSDI, CSDI, GSL) and DTR index in the baseline period 1970-2011.

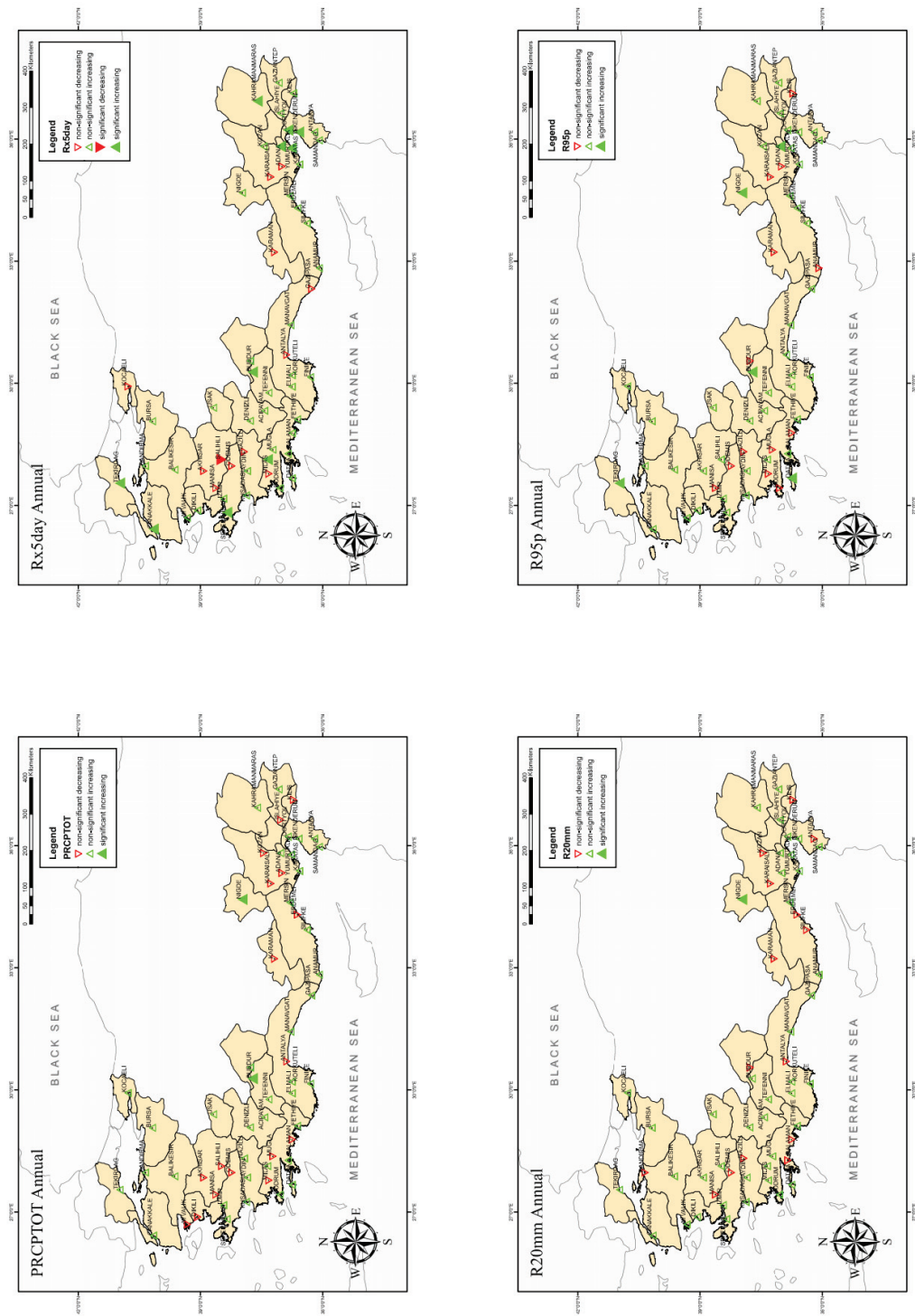


Figure 3.14. Annual trends of intensity indicators (PRCPTOT, Rx5day, R20mm, R95p) in the baseline period 1970-2011.

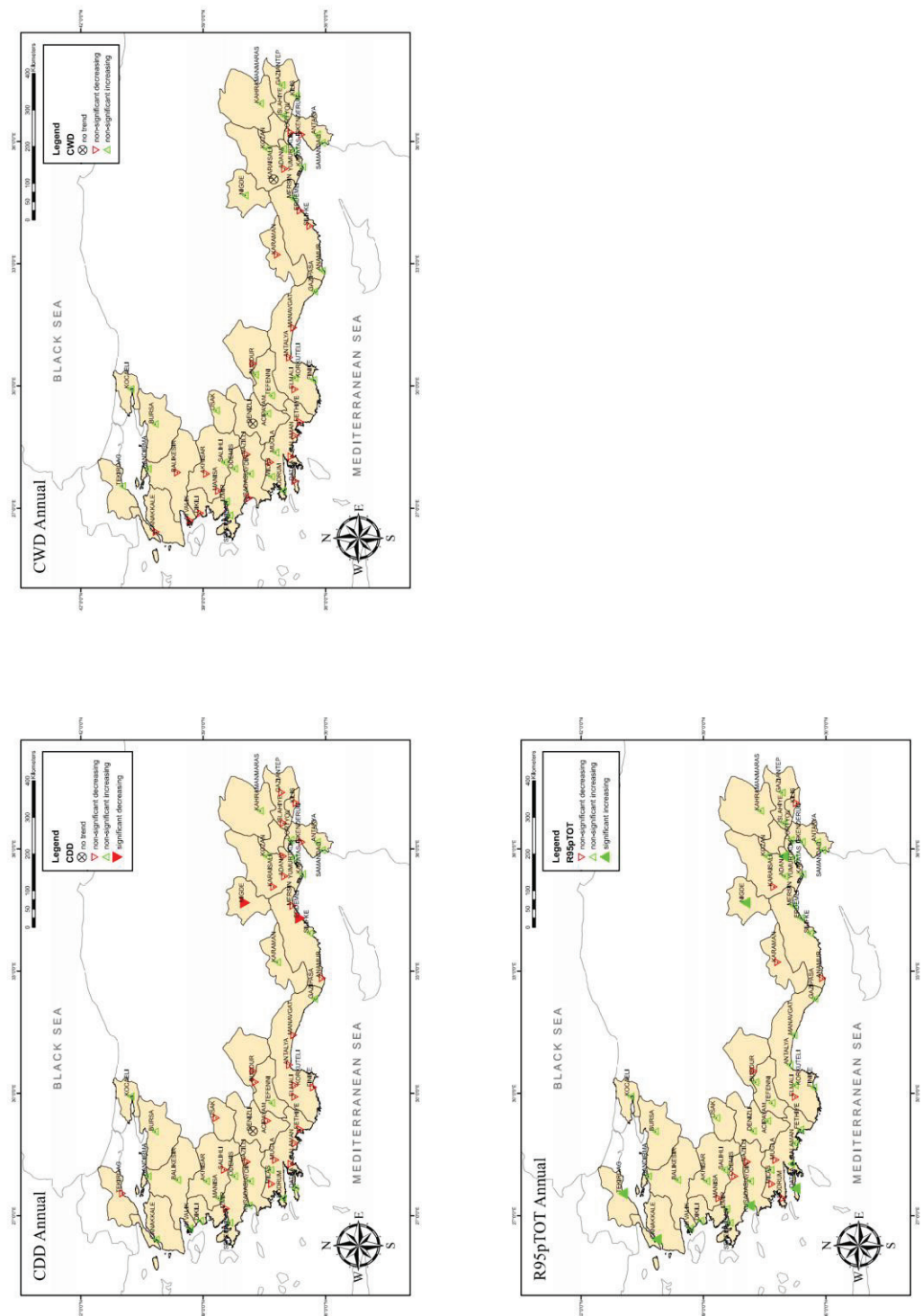


Figure 3.15. Annual trends of other precipitation indicators (CDD, CWD, R95pTOT) in the baseline period 1970-2011.

3.4.2 Seasonal Trends

Seasonal trends of climate indices have also been examined and the number of stations with positive and negative trends has been shown in Table 3.10. Spatial distributions of seasonal trends of climate indices have been given in Appendix B. According to the table, 8 temperature indices (SU25, TR20, TXx, TNn, TNx, TXn, TX90, TN90) had a positive trend in spring season. In DTR index, the number of stations with negative and the number of stations with positive trends are almost the same in spring season. In this season, trends of CDD and Rx5day indicators have

Table 3.10 The number of stations with positive and negative seasonal trends in the baseline period 1970-2011. +, -, s+, s-, nt indicate non-significant positive, non-significant negative, significant positive, significant negative, no trend, respectively.

Indice	Season	+	-	s+	s-	nt	Indice	Season	+	-	s+	s-	nt
FD	MAM	4	45	0	5	3	TX10	MAM	3	40	0	14	0
	JJA	0	0	0	0	57		JJA	0	4	0	53	0
	SON	8	28	0	2	19		SON	14	27	1	15	0
	DJF	8	40	2	7	0		DJF	12	44	0	1	0
ID	MAM	3	13	0	1	40	TX90	MAM	33	4	20	0	0
	JJA	0	0	0	0	57		JJA	9	2	46	0	0
	SON	7	0	0	0	50		SON	28	2	26	1	0
	DJF	8	18	1	0	30		DJF	15	0	42	0	0
SU25	MAM	34	5	18	0	0	TN10	MAM	6	19	0	32	0
	JJA	17	2	38	0	0		JJA	0	0	0	57	0
	SON	37	9	11	0	0		SON	2	13	0	42	0
	DJF	22	2	6	0	27		DJF	9	36	1	11	0
TR20	MAM	30	4	13	0	10	TN90	MAM	26	3	28	0	0
	JJA	0	0	57	0	0		JJA	1	0	56	0	0
	SON	15	0	35	0	7		SON	8	0	49	0	0
	DJF	2	0	0	0	55		DJF	38	5	14	0	0
TXx	MAM	41	12	3	0	1	CDD	MAM	34	23	0	0	0
	JJA	19	2	36	0	0		JJA	28	29	0	0	0
	SON	41	3	12	1	0		SON	19	35	0	2	1
	DJF	17	0	40	0	0		DJF	46	11	0	0	0
TNn	MAM	30	3	24	0	0	CWD	MAM	18	38	0	1	0
	JJA	0	0	57	0	0		JJA	11	40	0	6	0
	SON	21	5	31	0	0		SON	47	5	4	0	1
	DJF	30	18	8	1	0		DJF	26	26	2	2	1
TNx	MAM	24	4	29	0	0	R20mm	MAM	23	32	0	2	0
	JJA	2	1	54	0	0		JJA	28	23	2	2	2
	SON	22	0	35	0	0		SON	37	12	5	0	3
	DJF	36	2	18	0	1		DJF	39	14	1	0	3
TXn	MAM	40	1	15	0	1	Rx5day	MAM	29	25	0	2	1
	JJA	3	0	54	0	0		JJA	18	33	1	4	1
	SON	33	15	9	0	0		SON	45	4	8	0	0
	DJF	36	17	2	0	2		DJF	34	21	2	0	0
DTR	MAM	22	18	7	10	0	PRCPTOT	MAM	22	33	0	1	1
	JJA	8	17	13	19	0		JJA	16	33	0	6	2
	SON	8	19	4	25	1		SON	48	4	5	0	0
	DJF	25	17	6	9	0		DJF	34	20	1	0	2

increased while trends of CWD, R20mm and PRCPTOT indicators have been decreasing. FD, TX10 and TX90 indicators have decreasing trend and ID has no trend at most stations in spring season in the baseline period. TNn, TNx, TXn, TXx, SU25 and TR20 have increased at most stations in summer season. TNx at Dalaman station, TXx at Kozan and Ceyhan stations, SU25 at Canakkale and Dikili stations have showed decreasing trend in summer season of baseline period but they are not significant trends. FD and ID indicators had no trend at any stations in as can be seen in Appendix B. While TN10 and TX10 have decreased significantly at all stations, TN90 and TX90 indices have showed positive trend through the region during summer season (except TX90 at Ceyhan and Kozan stations). Precipitation indices have showed decreasing trend in summer generally, but R20mm index had mostly positive trend. And, the number of stations with positive trend and the number of stations with negative trend are almost the same in summer season. Autumn trends of TNn, TNx, TXn, TXx, SU25 and TR20 indices have increased at most stations in the baseline period. Especially, most of the trends of TNn, Tnx and TR20 are significant. There has been negative trend observed in autumn season in FD, TN10 and TX10 indices of most of the stations, while there has been no trend for ID index. And, TN90 and TX90 indices have increased significantly (except negative trend of TX90 index at Kozan, Karaisali and Ceyhan stations.). In autumn season, DTR and CDD indices have reduced at most stations. CWD, Rx5day, R20mm and PRCPTOT indicators have showed increasing trend, even if they were not significant mostly. TNn, TNx, TXn and TXx have showed increasing trend in winter season mostly. But there has been a significant negative trend in TNn index of Balikesir station. No trend has been observed in SU25 and TR20 indices in this season of the baseline period. While FD, TX10 and TN10 indicator have decreasing at most stations, TN90 and TX90 indices have showed positive trend during winter season. FD index had significant positive trend at Balikesir and Gazipasa stations, and TN10 index at Balikesir station. There has been no trend of ID index mostly over the region. Winter trends of DTR, CDD, Rx5day, R20mm and PRCPTOT indicators have increased in the baseline period. In CWD index, the number stations with positive trend and the

number of the stations with negative trend are the same in winter season. Summary of annual and seasonal trends of climate indices in the baseline period has been provided in Table 3.11.

Table 3.11 Annual and seasonal trends of climate indices in the baseline period. $\searrow$ denotes negative trend, $\leftrightarrow$ denotes no trend, $\nearrow$ denotes positive trend.

	Category	Indices	Annual	Spring	Summer	Autumn	Winter
Temperature indices	Percentile-based indices	TX10	$\searrow$	$\searrow$	$\searrow$	$\searrow$	$\searrow$
		TX90	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
		TN10	$\searrow$	$\searrow$	$\searrow$	$\searrow$	$\searrow$
		TN90	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
	Absolute indices	TXx	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
		TNn	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
		TNx	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
		TXn	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
	Threshold indices	FD	$\searrow$	$\searrow$	$\leftrightarrow$	$\searrow$	$\searrow$
		ID	$\searrow$	$\searrow$	$\leftrightarrow$	$\searrow$	$\searrow$
		SU25	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\leftrightarrow$
		TR	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\leftrightarrow$
	Duration indices	GSL	$\nearrow$	NA	NA	NA	NA
		WSDI	$\nearrow$	NA	NA	NA	NA
		CSDI	$\searrow$	NA	NA	NA	NA
	Other index	DTR	$\searrow$	$\nearrow$	$\searrow$	$\searrow$	$\nearrow$
Precipitation indices	Intensity indices	R20mm	$\nearrow$	$\searrow$	$\nearrow$	$\nearrow$	$\nearrow$
		Rx5day	$\nearrow$	$\nearrow$	$\searrow$	$\nearrow$	$\nearrow$
		PRCPTOT	$\nearrow$	$\searrow$	$\searrow$	$\nearrow$	$\nearrow$
		R95p	$\nearrow$	NA	NA	NA	NA
	Other indices	CDD	$\nearrow$	$\nearrow$	$\searrow$	$\searrow$	$\nearrow$
		CWD	$\nearrow$	$\searrow$	$\searrow$	$\nearrow$	$\nearrow$
		R95pTOT	$\nearrow$	NA	NA	NA	NA

3.5 Future Projections

Future projections of all analyses have been made for 2011-2050 time period. The appropriate models for precipitation and temperature that has been determined in Section 3.1 have been used to estimate future situation in terms of precipitation, temperature and climate indices by the middle of the 21st century.

3.5.1 Spatial Distributions of Precipitation and Temperature

For this thesis, 8 model couplings have been examined in Section 3.1 and the best fitted models have been selected for the analyses. To see the differences between the models, summary tables have been constructed. Annual and seasonal projected values of region-averaged precipitation, maximum and minimum temperature and their percentage change compared to baseline period have been shown in Table 3.12.

Table 3.12 Annual and seasonal projected values of region-averaged precipitation, maximum and minimum temperature and their percentage change in comparison to baseline period.

Precipitation (mm)	Baseline	Future Projection															
		1-1	% change	2-1	% change	2-2	% change	3-1	% change	3-2	% change	3-3	% change	4-1	% change	4-2	% change
Annual	697.60	775.25	11.13%	798.70	14.49%	892.10	27.88%	742.76	6.47%	764.86	9.64%	715.15	2.52%	804.46	15.32%	718.21	2.95%
Spring	165.88	199.41	20.22%	192.31	15.93%	232.87	40.39%	191.36	15.36%	187.77	13.20%	178.82	7.80%	170.85	3.00%	168.19	1.39%
Summer	33.53	52.61	56.92%	59.65	77.90%	104.04	210.31%	58.89	75.66%	55.00	64.04%	38.46	14.70%	69.67	107.81%	42.45	26.62%
Autumn	165.35	154.72	-6.43%	181.12	9.54%	211.21	27.74%	185.69	12.30%	173.45	4.90%	174.77	5.70%	262.18	58.56%	166.15	0.49%
Winter	327.16	369.38	12.91%	357.68	9.33%	343.55	5.01%	303.67	-7.18%	345.14	5.50%	319.94	-2.21%	302.57	-7.51%	340.90	4.20%

Tmax (°C)	Baseline	Future Projection															
		1-1	% change	2-1	% change	2-2	% change	3-1	% change	3-2	% change	3-3	% change	4-1	% change	4-2	% change
Annual	22.27	22.48	0.93%	22.44	0.75%	22.47	0.91%	23.17	4.03%	23.76	6.70%	23.31	4.69%	22.86	2.65%	22.89	2.78%
Spring	20.51	21.09	2.84%	20.34	-0.80%	20.45	-0.28%	21.45	4.59%	22.17	8.08%	21.69	5.75%	21.65	5.54%	21.44	4.55%
Summer	31.67	32.26	1.87%	32.19	1.65%	32.26	1.89%	32.80	3.59%	33.28	5.10%	33.07	4.42%	32.44	2.43%	32.37	2.24%
Autumn	24.20	24.40	0.82%	24.92	2.95%	24.75	2.25%	25.07	3.59%	25.61	5.81%	25.08	3.62%	24.17	-0.15%	24.59	1.61%
Winter	12.70	12.18	-4.09%	12.34	-2.84%	12.46	-1.96%	13.42	5.62%	13.99	10.15%	13.54	6.56%	13.21	4.01%	13.21	3.94%

Tmin (°C)	Baseline	Future Projection															
		1-1	% change	2-1	% change	2-2	% change	3-1	% change	3-2	% change	3-3	% change	4-1	% change	4-2	% change
Annual	11.36	12.01	5.75%	11.81	3.96%	12.05	6.08%	12.45	9.59%	13.14	15.66%	12.67	11.54%	12.51	10.13%	12.35	8.72%
Spring	9.56	10.50	9.81%	9.55	-0.15%	9.88	3.33%	10.42	9.02%	11.24	17.52%	10.71	11.99%	10.60	10.90%	10.52	10.05%
Summer	19.41	20.35	4.82%	20.15	3.80%	20.32	4.67%	20.74	6.85%	21.33	9.89%	21.08	8.59%	21.00	8.17%	20.57	5.95%
Autumn	12.48	13.11	5.01%	13.46	7.80%	13.77	10.32%	13.74	10.07%	14.34	14.91%	13.87	11.09%	13.52	8.33%	13.40	7.38%
Winter	3.98	4.13	3.83%	4.14	4.09%	4.27	7.13%	4.99	25.38%	5.65	41.81%	5.14	29.00%	4.98	24.97%	4.97	24.70%

According to Table 3.12, -considering the best models for precipitation and temperature- it can be said the both precipitation and temperature will show increasing by the middle of the century.

Annual precipitation distribution of the region based on the best fitted model (Model 3-2) determined in Section 3.1.1 have been shown in Figure 3.16. According to this figure, maximum precipitation amounts will be observed in southwestern part of the region, at Bursa and Kocaeli stations and in western Mediterranean coast in 2011-2050 in annual. On average, 764.86 mm annual precipitation will occur through the region and individually, maximum precipitation amount is expected to be observed at Korkuteli station with 1525.58 mm while the minimum is at Karaman station with 359.28 mm. For maximum and minimum temperature Model 4-2 has been determined as the best model in Section 3.1.2. Annual region-averaged maximum temperature will be 22.89°C based on this model. Manavgat, Antalya, Gazipasa stations and stations around Adana will be warmer parts of the region annually in this period. Maximum temperature will take the highest value at Manavgat station with 26.92°C and the lowest will be 14.85°C at Korkuteli station. The stations Elmali, Korkuteli, Bursa, Nigde, Kahramanmaras and Karaman will experience lower values of annual average of maximum temperature (Figure 3.17). Annual average of minimum temperature distribution in the 2011-2050 has been presented in Figure 3.17. Annual region-averaged minimum temperature is projected to be measured as 12.35°C. Lower annual minimum temperature values will be seen at the stations Bursa, Usak, Elmali, Korkuteli, Karaman, Nigde and Kahramanmaras. Higher values will be experienced at the stations Anamur, around Karatas and Antakya stations. The highest and the lowest minimum temperature will be observed at Karatas station with 17.71°C and at Korkuteli station with 3.53°C, respectively.

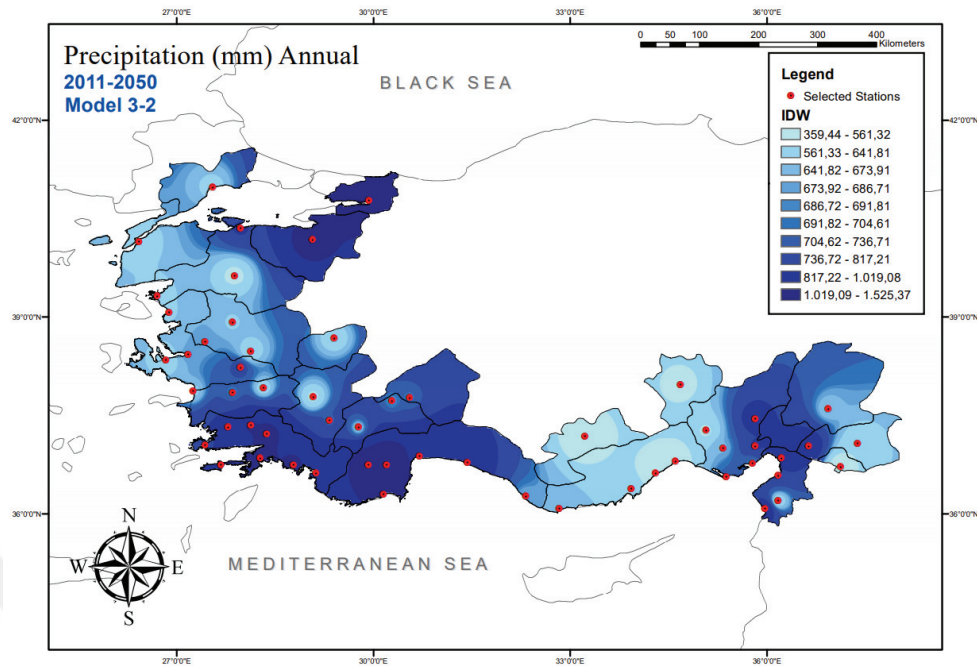


Figure 3.16. Annual precipitation distribution of the region in the 2011-2050.

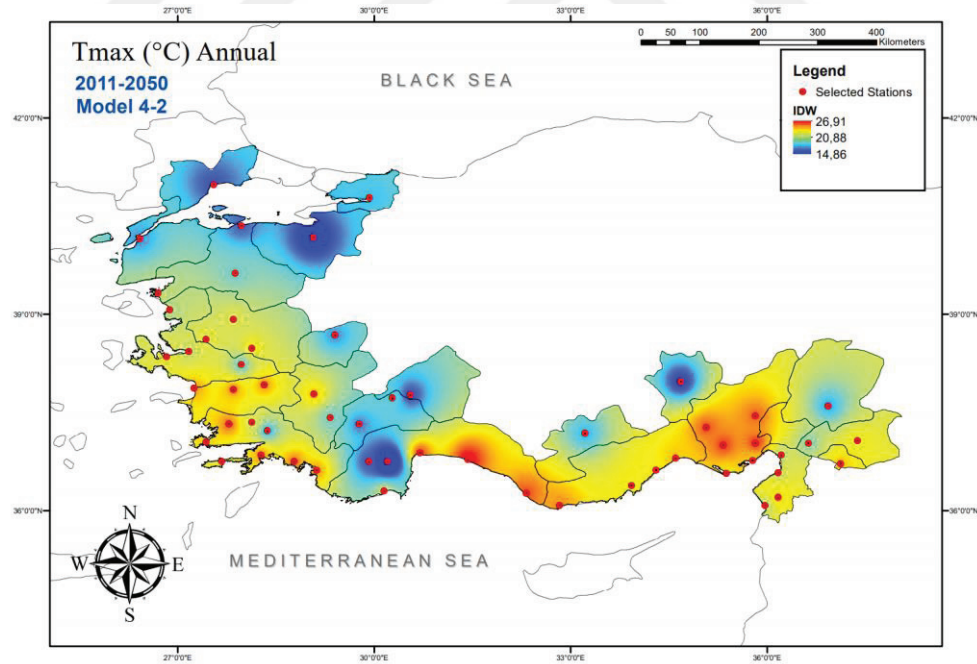


Figure 3.17. Annual maximum and minimum temperature distributions of the region in the 2011-2050.

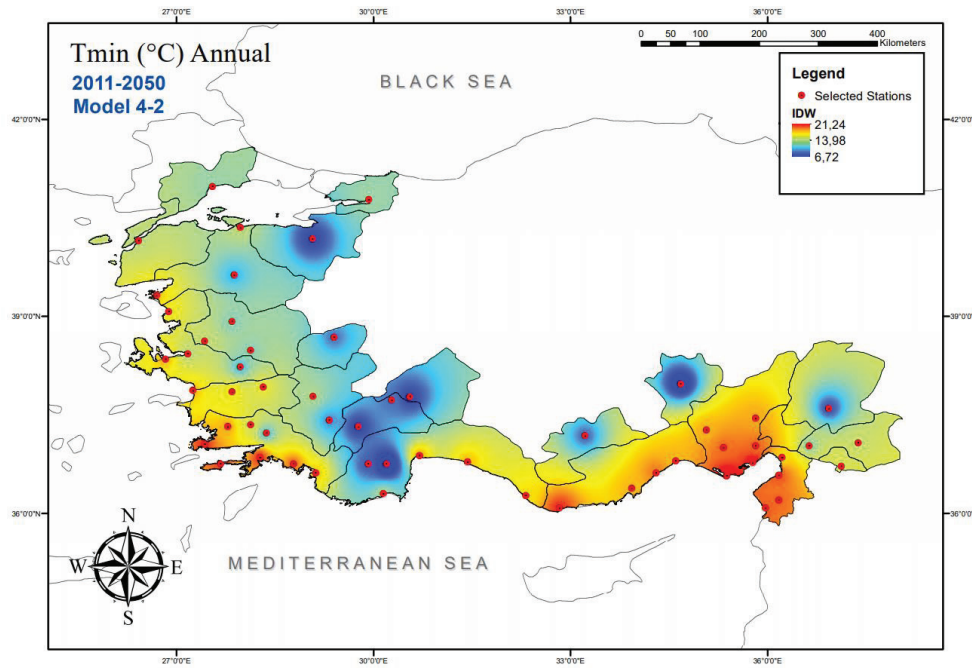


Figure 3.17. (cont'd)

Seasonal distributions of precipitation, maximum and minimum temperature have been given in Appendix C. In spring season, the higher amount of precipitation is expected to be observed at Bursa, Kocaeli, Korkuteli, Kozan, Islahiye, Mugla and Yatagan stations based on Model 3-2. The stations Canakkale, Gazipasa, Anamur, Silifke, Erdemli and Mersin will have a drier season. While region average of precipitation is 187.77 mm in spring, maximum precipitation will be measured at Korkuteli with the value of 438.82 mm and Erdemli station will have the lowest value as 74.11 mm in this season. Average maximum temperature in spring is expected to be 21.44°C. According to the average maximum distribution in the spring season, the stations within Adana city will be experiencing higher temperatures while Bursa, Tekirdag, Elmali, Korkuteli and Nigde stations will be having lower temperatures. The projected highest and lowest maximum temperature values for this season are 25.13°C at Ceyhan station and 13.15°C at Korkuteli station, respectively.

In spring, average minimum temperature will take the value of 10.52°C. Higher minimum temperature values will be observed at Anamur, Samandag, Antakya and

stations within Adana city. Bursa, Tefenni, Isparta, Korkuteli, Nigde, Karaman and Kahramanmaraş will be cooler than other stations. The highest and the lowest values of minimum temperature will be measured as 15.56°C at Karatas station and 2.02°C at Korkuteli station.

Bursa, Kocaeli and Korkuteli stations will take precipitation above the average in summer season -which is 55.00 mm- according to 2011-2050 projection. Aegean coast and the stations Gazipasa, Anamur, Silifke, Erdemli and Mersin will be drier part of the region in this period. Average maximum temperature will be 32.37°C in summer. Maximum temperature will reach to greater degrees at stations Denizli, Milas, Gaziantep, Manavgat and the stations within Aydin city during season. The greatest maximum temperature will be observed at Milas station with the value of 36.26°C. Higher minimum temperatures will be seen at the stations within Adana city. The average of minimum temperature in summer season will be 20.57°C and the lowest at Korkuteli station with 10.83°C.

In autumn season of 2011-2050 period, Bursa, Kocaeli and the stations within Mugla and Antalya cities will take greater amounts of precipitation, while the stations Erdemli, Mersin, Karaman and Nigde will be experiencing a dry season. The region average precipitation in this season will be measured as 173.45 mm and the maximum and minimum values will be 337.45 mm at Dalaman station and 60.89 mm at Karaman station. The average of maximum temperature will reach to higher degrees at Manavgat and the stations within Adana city. The greatest maximum temperature value will be 29.22°C at Ceyhan station. In this season, higher values of average minimum temperature will be seen at the stations Anamur, Samandag, Antakya and stations within Adana city while lower degrees will be measured at the stations Bursa, Isparta, Tefenni, Korkuteli, Nigde and Kahramanmaraş. The lowest minimum temperature will be at Korkuteli station with 3.85°C.

The Mediterranean coast and the stations Bursa and Kocaeli will take higher amounts of precipitation in the winter season of 2011-2050 and the maximum precipitation will be measured as 641.11 mm at Marmaris station. The winter average of

precipitation during this period will be 345.14 mm. Interior parts of Aegean, the stations Karaman, Nigde, Gaziantep and Kilis will have a dry winter season. The lowest precipitation will occur at Karaman station with 114.96 mm. In the winter season, greater values of average maximum temperature will be seen at the stations Manavgat, Gazipasa and Anamur. The greatest maximum temperature value will be observed at Gazipasa with 18.30°C. The region average of maximum temperature during winter season will be 13.21°C while the average of minimum temperature will be 4.97°C. The lowest temperature degree (on average) will be experienced at Nigde station with -3.34°C.

3.5.2 Trends in Precipitation and Temperature

3.5.2.1 Annual Trends

The best models for precipitation and temperature -which are Model 3-2 and Model 4-2, respectively- have been used for trend calculation as well. Annual precipitation, in general, is expected to show increasing trend across the study area and 3 of them are significant increasing at 5% level (Canakkale, Dikili and Izmir). However, negative trend will be observed at 10 stations as it can be seen in Figure 3.18 and none of them is significant decreasing.

For the temperature trend calculations, Model 4-2 has been used as stated before. Significant positive trend at 5% level is projected to be observed in terms of both maximum and minimum temperatures at each and every station in 2011-2050.

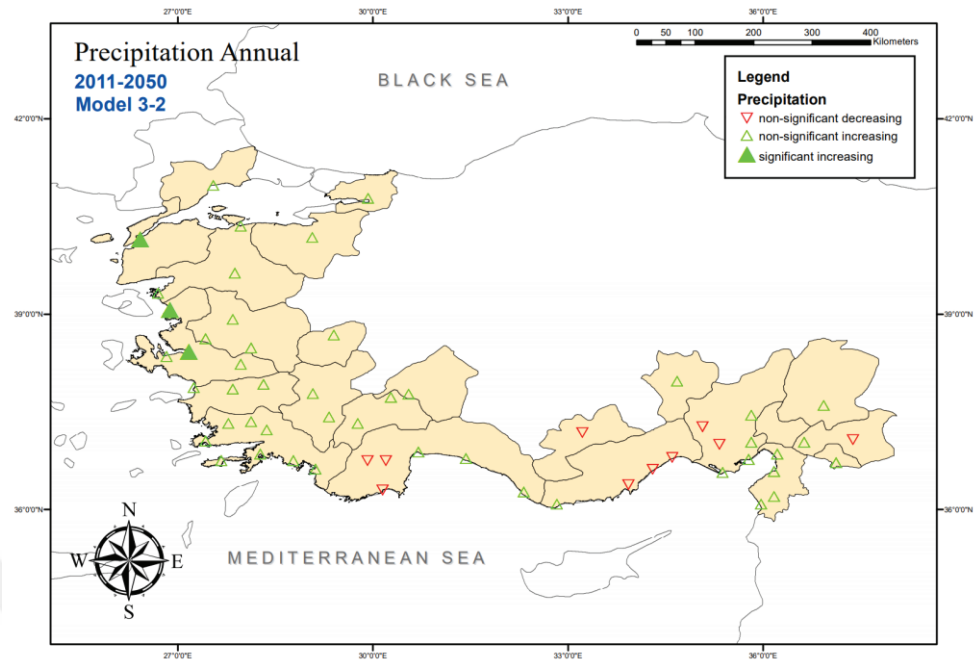


Figure 3.18 Spatial distribution of annual trends in precipitation of the region in the 2011-2050.

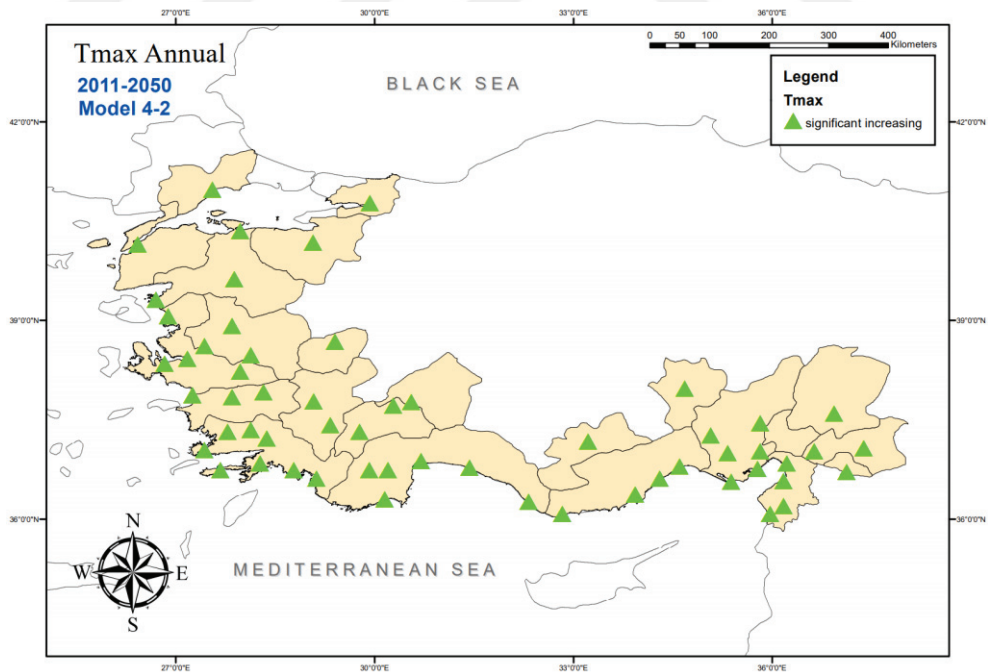


Figure 3.19. Spatial distributions of annual trends in maximum and minimum temperature of the region in the 2011-2050.

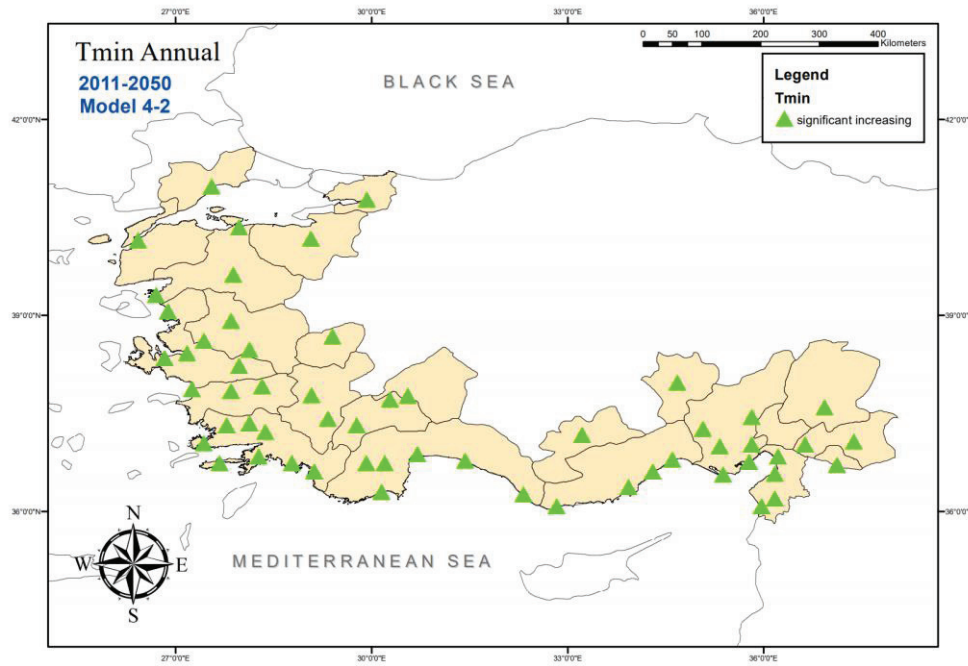


Figure 3.19. (cont'd)

3.5.2.2 Seasonal Trends

The Aegean and the Mediterranean coasts will be having a drier season in spring of 2011-2050 period, especially there will be a significant decreasing trend at Ayvalik station. Moreover, 22 stations within the cities of Aydin, Mugla, Denizli, Usak and Burdur will show increasing trend. In general, significant positive trend will be observed across the region in terms of maximum and minimum temperature.

In summer season of 2011-2050, the Aegean coast will have a positive trend in precipitation while 14 stations will have negative trend. Significant increasing precipitation trend is expected to be observed at Ayvalık, Dikili and Manisa in this season. There will be significant increasing temperature trend observed at each station, except non-significant positive maximum temperature trend at Canakkale and Dikili stations.

The Aegean coast will be experiencing wetter season during autumn as well as summer while 13 stations will have decreasing precipitation trend. There will be

significant increasing temperature trend observed at each station as well, except non-significant positive maximum temperature trend at Milas, İzmir and Dikili stations.

According to the winter trends of precipitation, it is seen that an increasing trend will be dominant across the region. 7 stations within the Aegean will be showing significant positive trend at 5% level. Although, at 4 stations there will be a negative trend in precipitation in this season. Temperatures will also be increasing during this season in the 2011-2050. 25 stations in maximum temperature and 34 stations in minimum temperature will have increasing trend. In contrast, negative trend will be observed at 3 stations which are Balıkesir, Nazilli and Gazipasa in terms of minimum temperature. Spatial distributions of all seasonal trends in precipitation and temperature within 2011-2050 time period can be seen in Appendix D.

3.5.3 Trends of Climate Indices

3.5.3.1 Annual Trends

Annual trends of intensity indicators (PRCPTOT, Rx5day, R20mm and R95p) in 2011-2050 have been shown in Figure 3.20. Intensity indicators are precipitation-related indicators, so that Model 3-2 have been used for the analyses of those. According to Figure 3.20, PRCPTOT will have a positive trend at 52 stations and 6 of them are significant at 5% level. Although, there will be decreasing trend at 8 stations. Rx5day index will show increasing trend at 36 stations (9 of them are significant) while decreasing trend at 21 stations (only Bursa station is significant). R20mm index will increase across the region, especially through the Aegean, while it will reduce at 18 stations. There will be decreasing in R95p index at 20 stations (significant decreasing at Silifke station) and increasing at 37 stations (3 of them are significant). The increments in those intensity indicators will be observed mostly through the Aegean. Annual trends of other precipitation-related indices which are CDD, CWD and R95pTOT have been shown in Figure 3.21 and Model 3-2 have been used for them as well. CDD index will be showing a mixed pattern through the

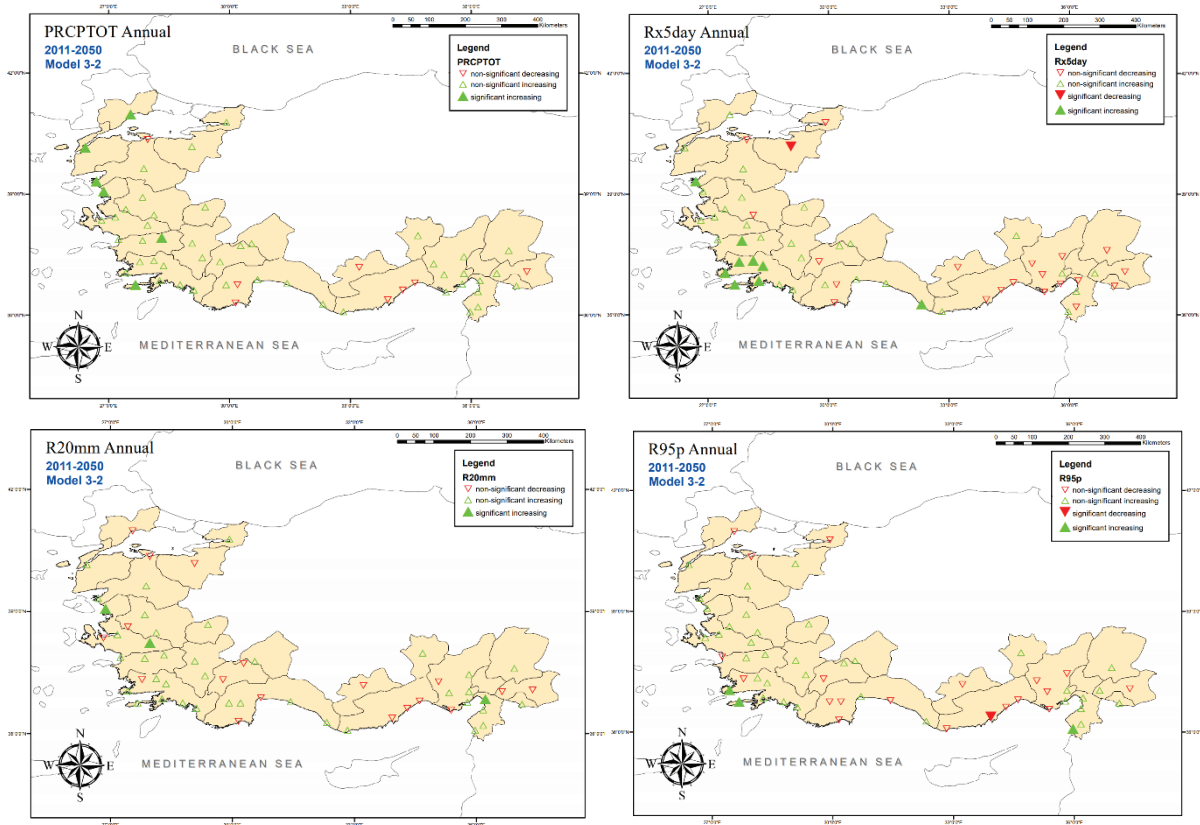


Figure 3.20. Annual trends of PRCPTOT, Rx5day, R20mm and R95p indices in 2011-2050.

region. It is expected to be seen negative trend at 30 stations while positive trend at 27 stations. CWD index will have increasing trend through the Aegean and southeastern part of the region and the increasing will be significant at 3 stations. R95pTOT will have positive trend at 33 stations and negative trend at 24 stations. 6 of the decreases and 1 of the increases will be significant at 5% level.

Model 4-2 has been used for the analyses of the indices to be examined hereafter since they are related with temperature. Annual trends of percentile-based indicators (TX10, TX90, TN10, TN90) have been presented in Figure 3.22. According to model results, TX10 and TN10 will have a significant decreasing trend in 2011-2050, while TX90 and TN90 will be increasing significantly. Only 2 stations, which are Dikili and Milas, will have non-significant negative trend in TX10. In Figure 3.23., trends

of absolute (TNn, TXn, TNx and TXx) indicators have been shown. There will be increasing trend observed in all of those indicators across the region. 52 stations in TNx and 38 stations in TXx are expected to show significant increasing trend. Only 2 stations (Kahramanmaras and Kilis) will have non-significant negative trend in TNn index. Annually, FD and ID will be reducing across the region by the middle of the century as it can be seen in Figure 3.24. The Mediterranean coast will not show any trend in ID index while only 1 station have no trend in FD index. There will be significant positive trend observed in annual trends of SU25 and TR20 indices at almost every station (Figure 3.24.). Annual trends of duration indicators (WSDI, CSDI, GSL) and DTR index in 2011-2050 have been shown in Figure 3.25. There will be a significant positive trend in WSDI across the region while significant negative in CSDI. GSL and DTR indices will increase at most stations in this period. The significant increasing in DTR is expected to be observed in interiors of the Aegean and south part of the region.

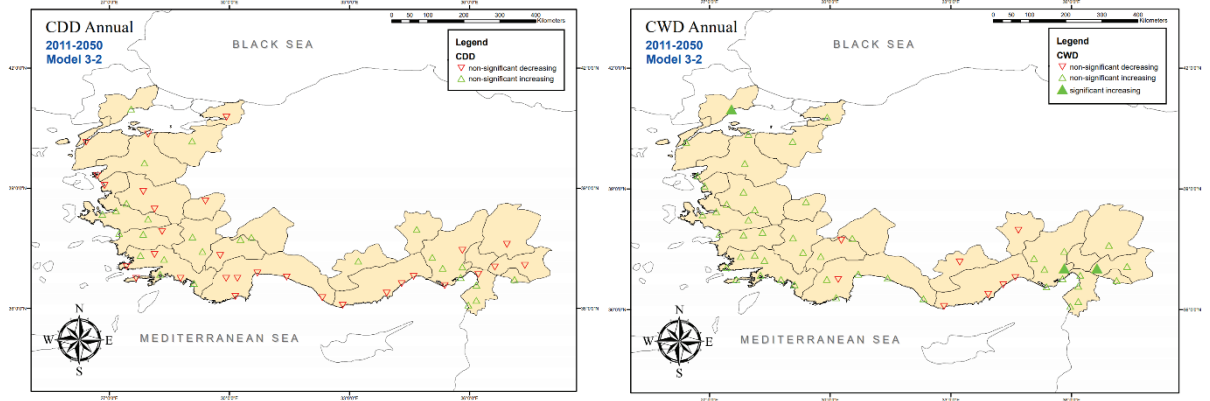


Figure 3.21. Annual trends of CDD, CWD and R95pTOT indices in 2011-2050.

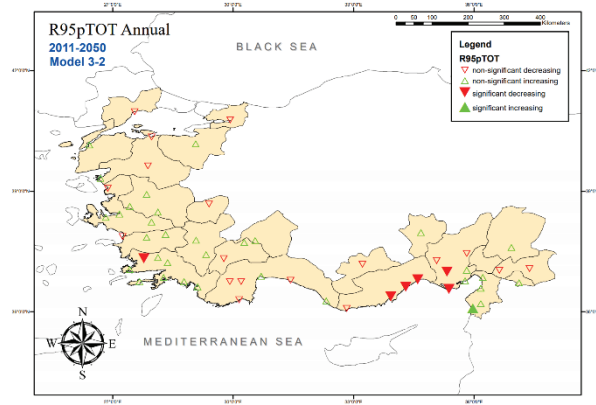


Figure 3.21. (cont'd)

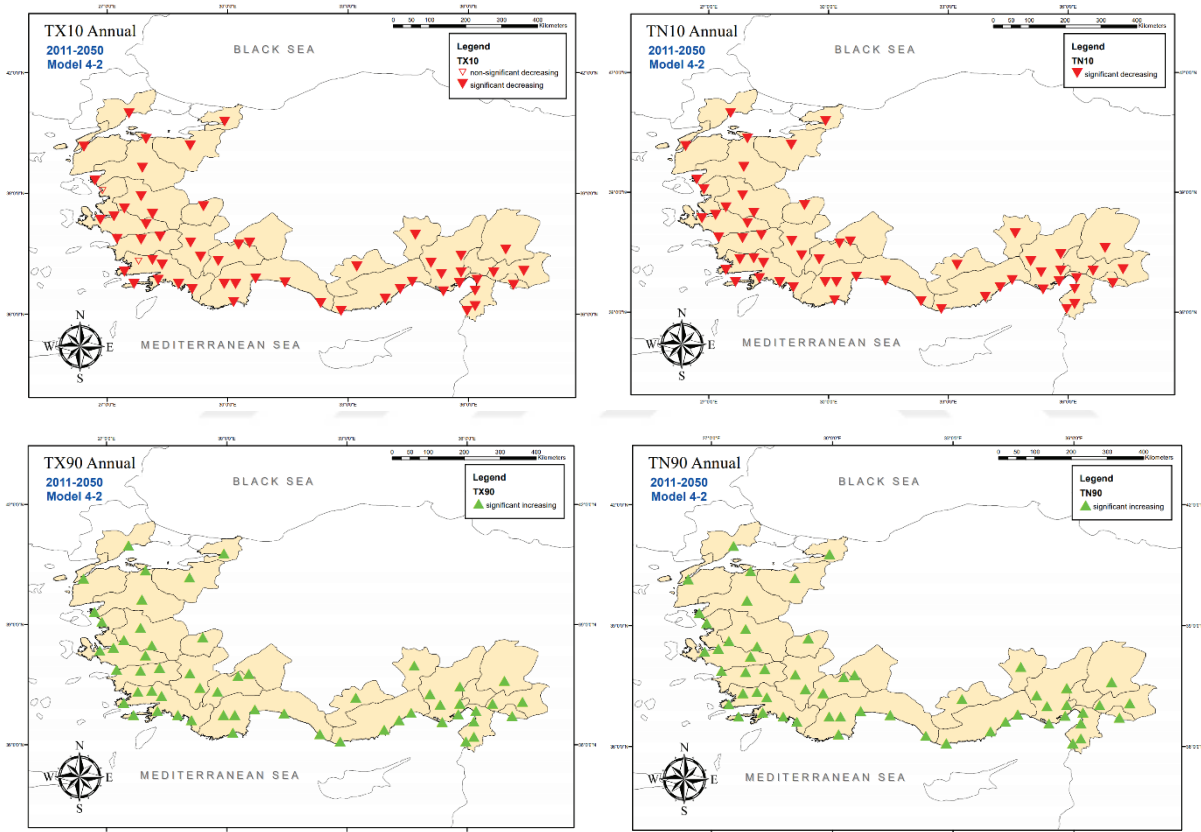


Figure 3.22. Annual trends of TX10, TN10, TX90 and TN90 indices in 2011-2050.

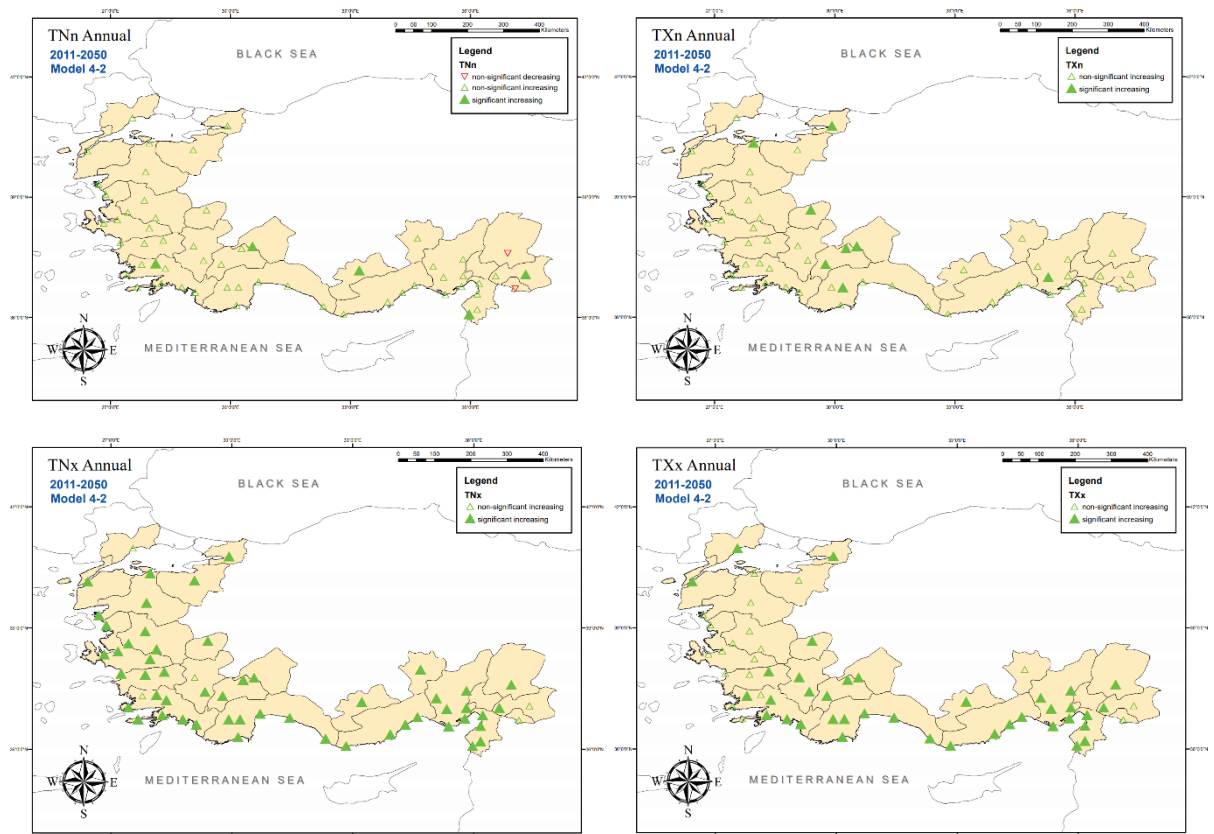


Figure 3.23. Annual trends of TNn, TXn, TNx and TXx indices in 2011-2050.

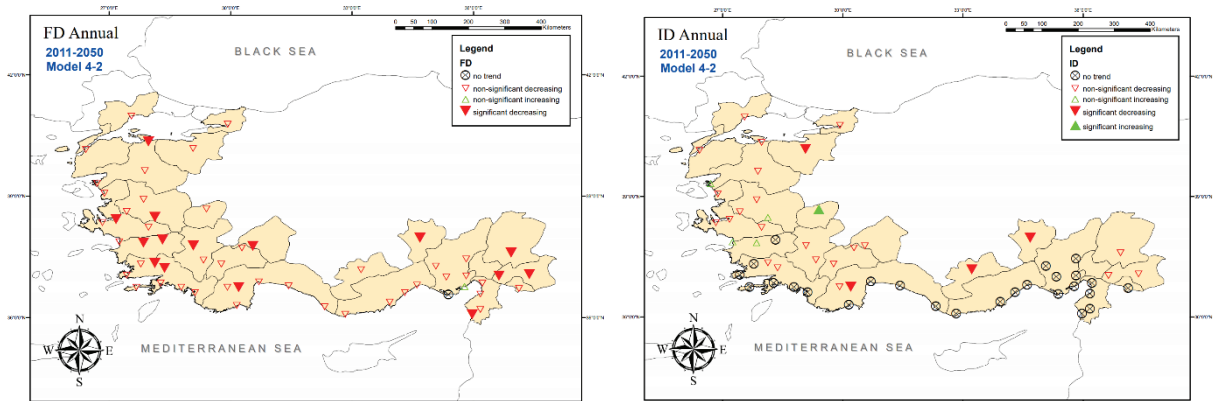


Figure 3.24. Annual trends of FD, ID, SU25 and TR20 indices in 2011-2050.

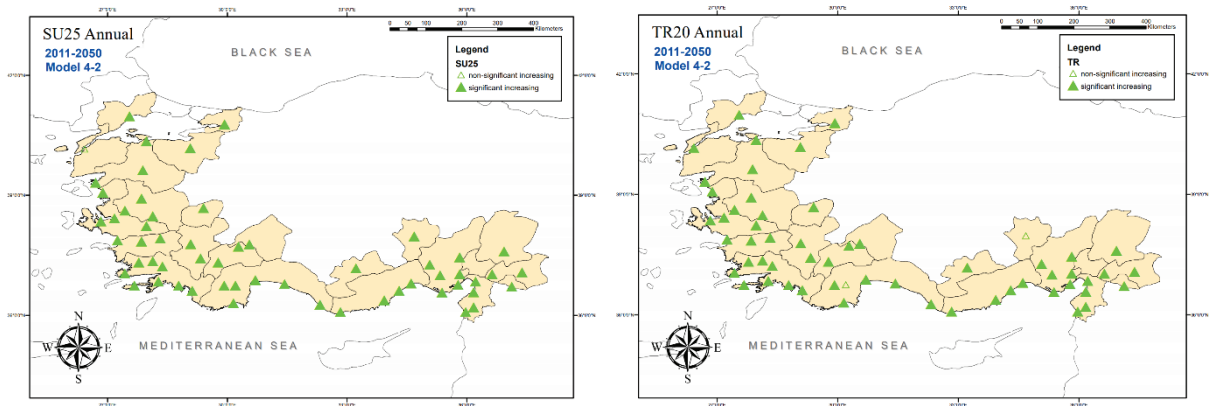


Figure 3.24. (cont'd)

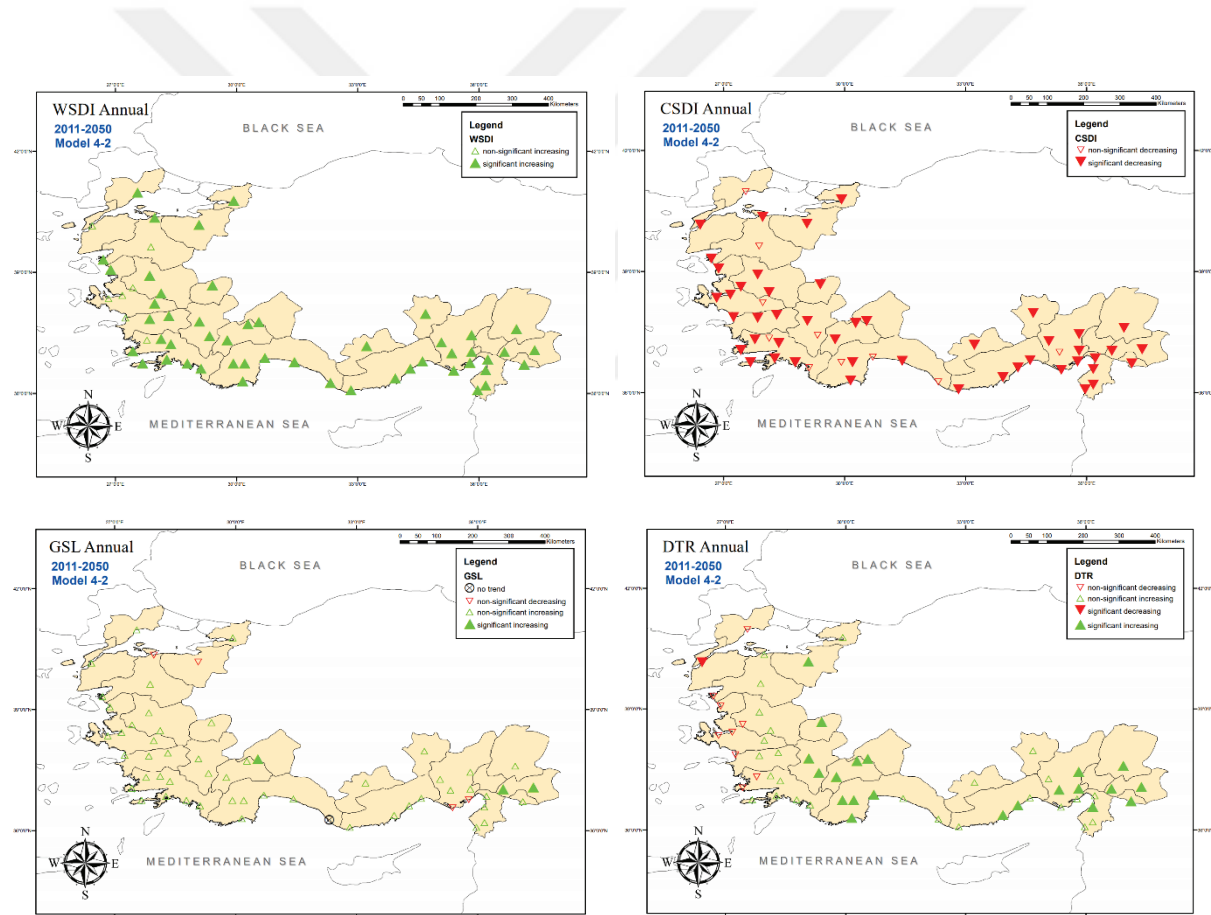


Figure 3.25. Annual trends of WSDI, CSDI, GSL and DTR indices in 2011-2050.

3.5.3.2 Seasonal Trends

3.5.3.2.1 Spring Trends

Model 3-2 has been used for the seasonal analyses of precipitation-related indicators, as well. In general, intensity indicators which are PRCPTOT, Rx5day and R20mm will have decreasing trend at most of the stations in spring. Especially in the Aegean coast and southeastern of the study area, PRCPTOT and Rx5day indicators will reduce. CWD index is expected to decrease across the region while CDD will have mixed pattern, but it will have negative trend in the Aegean.

Model 4-2 has been used for the seasonal analyses of temperature-related indices. TX10 index will be increasing in the Aegean while it is decreasing in the Mediterranean region. TN10 index will reduce at most stations and this reduction will be significant at 4 stations. TX90 and TN90 indicators will be significantly increasing in this season. TNn index will increase at 49 stations and decrease at 8 stations. TXn index will be reducing in the Aegean but it will be increasing through the Mediterranean (2 of them significant). TNx and TXx indicators will be significantly increasing as well. FD index will not have any trend through the coastal zones and interior parts of the region will show a mixed pattern. ID index will not be showing any trend in the region (except 1 station with increasing). SU25 will significantly increase in this season. TR20 index will not show any trend except for increasing in the Aegean. DTR index will be increasing in the interiors of the Aegean, the Mediterranean and the southeastern of the study area while decreasing in the Aegean coast (See Appendix E).

3.5.3.2.2 Summer Trends

Spatial distributions of summer season trends of climate indices have been provided in Appendix F. In general, PRCPTOT, Rx5day, R20mm and CWD indicators will have increasing trend in the Aegean during summer in 2011-2050. However, it is

expected to be observed a mixed pattern in the rest of the study area. Moreover, CDD index will decrease at most stations in this season based on the Model 3-2.

TX10 and TN10 will be significantly decreasing while TX90 and TN90 will be increasing in summer. TNn index will show positive trend across the region, especially in the coastal zones the increasing will be significant. TXn will increase as well and the significant increasing will be observed in the Mediterranean region. Both TNx and TXx indicators will be significantly increasing in summer. FD and ID indicators will not have any trend across the region. SU25 and DTR indicators will increase at most of the station, however, those indicators will have negative trend in the Aegean coast. Moreover, TR20 will be significantly increasing across the region in summer (See Appendix F).

3.5.3.2.3 Autumn Trends

Autumn trends of climate indices have been presented in Appendix G. PRCPTOT index will increase through the region except for decreasing at 14 stations. For the indicators Rx5day, R20mm and CDD, there will be increasing trend in the Aegean while decreasing in the Mediterranean. Moreover, CWD will be reducing across the Aegean and southeastern part of the study area in autumn.

TX90 and TN90 indices will be increasing significantly during autumn in 2011-2050, while TN10 and TX10 indices will have a decreasing. Especially, the south of the region will have significant negative trend in TN10 index. TNx and TXx indicators will have significant positive trend. Significant increasing trend will also be observed in TNn and TXn indicators through the Mediterranean. FD will not have any trend in coastal areas, but there will be a negative trend at interiors. ID index will also not have any trend across the region except 2 stations. SU25 and TR20 indicators will increase significantly at most stations during autumn. Additionally, DTR index will have mixed pattern, trend will be increasing in the interiors while decreasing in the coasts of the Aegean (See Appendix G).

3.5.3.2.4 Winter Trends

Winter trends of climate indices in 2011-2050 have been shown in Appendix H. PRCPTOT, Rx5day, R20mm and CWD indicators will have increasing trend at most stations, especially in the Aegean while CDD index will be reducing across the region during winter in 2011-2050.

TX10 and TN10 indices will have a negative trend across the region in this season, however positive trend will be observed through the northern of the Aegean. TX90 will significantly increase in the region and TN90 will also increase but only the trends in the Mediterranean will be significant. All absolute indicators (TNn, TXn, TNx, TXx) will increase during the winter in 2011-5050. Although there will be negative trends in TNn index at 19 stations and in TXn through the Mediterranean. FD and ID will be decreasing across the region, but for ID index there will not be any trend observed in the coastal zones. Both SU25 and TR20 indicators will not have any trend in this season as well, however in SU25 index of the southeastern part will increase. Furthermore, DTR will have both increasing and decreasing trends across the region, mixed pattern will be observed (See Appendix H).

Summary of the annual and seasonal trends of climate indices in 2011-2050 have been given in Table 3.13. Table 3.14, 3.15, 3.16, 3.17 and 3.18 shows the number of stations with significant trends in annual, spring, summer, autumn and winter, respectively. Additionally, annual and seasonal percentage changes of climate indices have been provided in Appendix I.

Table 3.13 Annual and seasonal trends of climate indices in 2011-2050. ↘ denotes negative trend, ↔ denotes no trend, ↗ denotes positive trend.

	Category	Indices	Annual	Spring	Summer	Autumn	Winter
Temperature indices	Percentile-based indices	TX10	↘	↘	↘	↘	↘
		TX90	↗	↗	↗	↗	↗
		TN10	↘	↘	↘	↘	↘
		TN90	↗	↗	↗	↗	↗
	Absolute indices	TXx	↗	↗	↗	↗	↗
		TNn	↗	↗	↗	↗	↗
		TNx	↗	↗	↗	↗	↗
		TXn	↗	↗	↗	↗	↗
	Threshold indices	FD	↘	↔	↔	↘	↘
		ID	↘	↔	↔	↘	↘
		SU25	↗	↗	↗	↗	↔
		TR	↗	↗	↗	↗	↔
	Duration indices	GSL	↗	NA	NA	NA	NA
		WSDI	↗	NA	NA	NA	NA
		CSDI	↘	NA	NA	NA	NA
	Other index	DTR	↗	↗	↗	↗	↗
Precipitation indices	Intensity indices	R20mm	↗	↗	↗	↗	↗
		Rx5day	↗	↘	↗	↗	↗
		PRCPTOT	↗	↘	↗	↗	↗
		R95p	↗	NA	NA	NA	NA
	Other indices	CDD	↗	↗	↘	↘	↘
		CWD	↗	↘	↘	↘	↘
		R95pTOT	↘	NA	NA	NA	NA

Table 3.14 The number of stations with significant positive and significant negative trends in annual.

Category	Index	ANNUAL															
		Baseline		Model 1-1		Model 2-1		Model 2-2		Model 3-1		Model 3-2		Model 3-3		Model 4-1	
		s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-
Temperature indices	Percentile-based indices	TX10	0	41	0	57	0	51	0	56	0	47	0	57	0	57	0
		TX90	50	1	53	0	54	0	16	0	57	0	55	0	57	0	57
		TN10	1	48	1	56	0	57	0	57	0	56	0	57	0	57	0
		TN90	51	0	56	1	56	0	42	0	57	0	56	0	57	0	57
	Absolute indices	TXx	29	0	14	0	3	0	19	0	41	0	7	0	30	0	38
		TNx	10	0	18	0	0	0	3	0	6	0	26	0	12	0	5
		TNx	46	0	26	0	28	0	10	0	48	0	31	0	56	0	52
		TXn	9	0	29	0	0	0	11	0	13	0	30	0	5	0	8
	Threshold indices	FD	2	8	0	38	0	2	0	20	0	31	1	16	0	15	0
		ID	0	0	0	8	1	0	0	6	0	10	0	10	0	3	1
		SU25	43	0	16	0	42	0	11	0	40	0	22	0	35	0	56
	Duration indices	TR	54	0	51	0	46	0	45	0	52	0	51	0	55	0	55
		GSL	2	0	10	0	2	0	8	0	5	0	7	0	16	0	3
		WSDI	27	0	9	0	41	0	0	0	37	0	18	0	33	0	50
Precipitation indices	Other index	CSDI	0	17	0	36	0	51	0	29	0	53	0	26	0	43	0
		DTR	8	21	0	11	9	0	0	7	0	14	0	9	0	0	21
		R20mm	1	0	3	0	0	0	8	2	4	0	3	1	0	3	9
	Intensity indices	Rx5day	10	1	3	0	0	0	12	0	3	1	9	0	0	4	6
		PRCPTOT	2	0	1	0	0	0	5	1	4	0	6	0	0	0	16
		R95p	5	0	9	0	1	0	17	3	6	2	3	1	3	0	8
	Other indices	CDD	0	2	0	0	0	0	0	23	0	0	0	12	0	27	0
		CWD	0	0	1	0	0	0	10	0	1	1	3	0	1	12	1
		R95pTOT	6	0	10	0	1	0	21	3	12	1	1	2	0	10	4
																	3

Table 3.15 The number of stations with significant positive and significant negative trends in spring.

Category		Index	SPRING																	
			Baseline		Model 1-1		Model 2-1		Model 2-2		Model 3-1		Model 3-2		Model 3-3		Model 4-1		Model 4-2	
			s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-
Temperature indices	Percentile-based indices	TX10	0	14	0	30	0	6	0	23	0	2	0	1	0	17	0	12	0	2
		TX90	20	0	51	0	0	0	1	0	2	0	0	0	7	0	53	0	53	0
		TN10	0	32	0	56	0	0	0	16	0	1	0	0	0	39	0	29	0	4
		TN90	28	0	56	0	6	0	5	0	11	0	3	0	23	0	54	0	47	0
	Absolute indices	TXx	3	0	35	0	3	0	0	0	2	0	2	0	1	0	36	0	35	0
		TNx	24	0	54	0	0	0	8	0	1	0	1	0	8	0	22	0	0	0
		TNx	29	0	45	0	7	0	2	0	15	0	9	0	20	0	41	0	39	0
		TXn	15	0	39	0	1	0	12	0	2	0	0	0	8	0	19	0	2	0
Threshold indices	FD	0	5	0	22	2	2	0	2	0	1	0	0	0	3	2	2	2	1	
	ID	0	1	0	1	0	0	0	4	0	0	0	0	0	1	0	0	0	0	
	SU25	18	0	33	0	0	0	1	0	0	0	1	0	7	0	42	0	32	0	
	TR	13	0	26	0	5	0	1	0	3	0	4	0	20	0	13	0	11	0	
Other index	DTR	7	10	3	0	0	0	0	0	1	2	0	0	1	0	0	0	18	0	
	R20mm	0	2	3	3	0	1	3	1	2	1	1	4	0	0	2	13	0	6	
	Rx5day	0	2	0	0	1	0	3	1	0	2	1	1	0	0	0	13	0	4	
	PRCPTOT	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0	18	0	12	
Precipitation indices	CDD	0	0	5	0	0	0	0	0	0	1	0	1	0	1	15	0	15	0	
	CWD	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	12	0	18	

Table 3.16 The number of stations with significant positive and significant negative trends in summer.

Category		Index	SUMMER																		
			Baseline		Model 1-1		Model 2-1		Model 2-2		Model 3-1		Model 3-2		Model 3-3		Model 4-1		Model 4-2		
			S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	
Temperature Indices	Percentile-based Indices	TX10	0	53	0	18	0	11	0	29	0	23	0	56	0	44	0	57	0	44	
		TX90	46	0	33	0	11	0	11	0	11	0	11	0	57	0	50	0	55	0	
		TN10	0	57	0	55	0	0	35	0	45	0	54	1	54	0	57	0	57	0	
		TN90	56	0	56	0	34	0	22	0	0	57	0	55	0	57	0	57	0	57	0
	Absolute Indices	TXx	36	0	23	0	2	0	11	0	0	57	0	39	0	56	0	49	0	50	0
		TNx	57	0	50	0	15	0	38	0	0	57	0	45	0	56	0	56	0	37	0
	Absolute Indices	TNx	54	0	52	0	24	0	19	0	0	57	0	55	0	57	0	57	0	57	0
		TXn	54	0	6	0	11	0	14	0	0	57	0	27	0	57	0	52	0	25	0
Threshold Indices	FD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	ID	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	SU25	38	0	3	0	4	0	1	0	0	46	0	8	1	20	0	16	0	6	0	
	TR	57	0	46	0	22	0	38	0	0	55	0	47	1	54	0	52	0	47	0	
Precipitation Indices	Other index	DTR	13	19	0	27	0	1	0	4	44	0	0	4	3	0	0	3	3	2	
	Intensity Indices	R20mm	2	2	4	1	1	0	9	3	19	5	2	0	0	4	0	9	2	0	
		Rx5day	1	4	6	0	4	0	6	1	12	15	3	0	0	7	1	24	4	0	
		PRCPTOT	0	6	3	0	4	0	7	1	12	16	3	0	0	0	1	27	3	0	
	Other Indices	CDD	0	0	1	1	1	1	3	1	52	0	0	2	10	0	20	1	2	0	
		Other Indices	CWD	0	6	4	0	4	0	2	4	7	13	3	0	0	9	0	24	3	0

Table 3.17 The number of stations with significant positive and significant negative trends in autumn.

Category	Index	AUTUMN															
		Baseline		Model 1-1		Model 2-1		Model 2-2		Model 3-1		Model 3-2		Model 3-3		Model 4-1	
		s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-	s+	s-
Temperature indices	Percentile-based indices	TX10	1	15	4	1	4	0	43	0	34	1	39	0	18	0	57
		TX90	26	1	2	0	0	14	0	57	0	54	0	56	0	53	0
		TN10	0	42	0	0	0	0	25	0	10	1	48	0	13	0	57
		TN90	49	0	0	0	0	39	0	56	0	55	0	55	0	56	0
	Absolute indices	TXx	12	1	0	0	0	7	0	57	0	42	0	51	0	52	0
		TNx	31	0	3	0	0	50	0	41	0	43	0	17	0	45	0
		TNx	35	0	0	0	0	23	0	53	0	53	0	40	0	54	0
		TXn	9	0	0	1	49	0	42	0	18	0	17	0	9	0	23
Precipitation indices	Threshold indices	FD	0	2	26	0	0	5	0	6	0	3	0	10	0	2	0
		ID	0	0	51	2	0	1	0	8	0	0	0	0	0	3	0
		SU25	11	0	0	0	0	12	0	44	0	16	1	25	0	34	0
		TR	35	0	5	0	0	33	0	40	0	34	1	47	0	50	0
	Other index	DTR	4	25	0	3	20	0	0	5	0	0	5	2	0	1	0
	Intensity indices	R20mm	5	0	0	0	0	2	4	3	0	0	1	3	2	5	4
		Rx5day	8	0	0	0	0	2	8	0	0	0	0	3	1	3	2
		PRCPTOT	5	0	1	0	0	2	9	0	0	0	0	0	1	1	3
Other indices		CDD	0	2	1	1	7	1	4	14	0	3	0	2	2	12	0
		CWD	4	0	2	0	0	3	8	0	0	0	1	0	1	0	6

Table 3.18 The number of stations with significant positive and significant negative trends in winter.

WINTER																				
Category	Index	Baseline		Model 1-1		Model 2-1		Model 2-2		Model 3-1		Model 3-2		Model 3-3		Model 4-1		Model 4-2		
		S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	S+	S-	
Temperature indices	Percentile-based indices	TX10	0	1	0	22	0	3	0	0	0	10	1	33	0	9	0	23	0	43
		TX90	42	0	27	0	0	1	0	55	0	33	0	52	0	28	0	16	0	0
		TN10	1	11	0	16	0	4	0	5	0	5	1	25	0	26	0	19	0	32
		TN90	14	0	47	0	0	0	2	0	38	0	45	0	34	0	20	0	8	0
	Absolute indices	TXx	40	0	30	0	0	0	2	0	56	0	35	0	52	0	35	0	32	0
		TNn	8	1	21	0	0	0	8	0	37	0	36	0	28	0	14	0	23	0
		TNx	18	0	21	0	2	0	0	0	44	0	35	0	34	0	22	0	18	0
		TXn	2	0	40	0	1	0	0	0	40	0	44	0	46	0	3	0	22	0
	Threshold indices	FD	2	7	0	26	0	2	0	1	0	16	0	29	1	13	0	14	0	12
		ID	1	0	0	8	0	1	0	4	0	6	0	9	0	6	0	2	0	4
SU25		6	0	3	0	2	0	0	0	10	0	1	0	5	0	1	0	5	0	
TR		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other index	DTR	6	9	0	1	6	0	0	0	1	0	1	12	2	0	0	0	4	0	
	R20mm	1	0	1	0	0	0	6	0	3	1	1	1	0	0	2	2	0	0	
	Rx5day	2	0	0	0	0	0	13	0	2	0	3	0	1	0	0	0	0	0	
	PRCPTOT	1	0	0	0	0	0	3	0	1	0	2	0	2	0	0	0	1	0	
Other indices	CDD	0	0	0	4	2	0	0	0	1	1	0	0	0	4	2	0	0	1	
	CWD	2	2	0	0	0	0	1	0	1	0	2	0	1	0	0	1	0	0	



CHAPTER 4

DISCUSSION

Based on the results of model performance, bias-adjusted models have been found more accurate than not-bias-adjusted models and therefore bias-adjusted models have been used for the analyses. According to time series and model statistics, models have been ranked and the models with top rankings have been selected. Model 3-2 has been determined as the best model for precipitation because of its lower value of RMSE (8.78 mm) than other models. By the same method, Model 4-2 with 5.82 mm RMSE and 0.81 r have taken the top rank for temperature.

According to spatial distributions of precipitation, higher amounts of precipitation in between 1970 and 2011 have been received by coastals of the study area and 46.9% of the precipitation occur during winter time. Inland areas of the region have been wetter than coastal areas in summer and 4.81% of the total annual precipitation occurs during this season. Based on Model 3-2, by the middle of the 21st century, precipitation amount -as average of the region- is likely to increase in both annual and seasonal. The highest increasing with 64.04% will occur in summer while the lowest increasing with 4.90% will occur in autumn. Region-averaged annual precipitation amount is expected to increase from 697.60 mm to 764.86 mm. The Aegean coasts will be wetter in summer, autumn and winter than it was before. While the coastal zones will be experiencing drier season in spring and summer, they will be wetter in autumn and winter. The changing precipitation amount and pattern mainly over the Aegean may reveal the need of revision on agricultural policy of the Aegean by the mid of the century based on the projections obtained from the models.

The region is likely to experience hotter and drier climate, although the pattern of temperature will remain almost the same, coastals are hot and inlands are cooler.

Increasing the temperature may induce more use of groundwater resources, and lower the groundwater levels (Fallah-Ghalhari et al., 2019). Moreover, excessive warmth may lead to an increasing in extreme weather events in terms of occurrence, duration and intensity (Stocker et al., 2013). Region-averaged annual maximum temperature will increase from 22.27°C to 22.89°C with the value of 2.78%. Average maximum summer temperature will be increasing with 0.7°C while average minimum winter temperature will be increasing with 0.99°C. Increasing temperature may increase the amount of evaporation and cause a change in precipitation pattern. Moreover, increasing in minimum temperatures will affect the frost-free season and it is important for agriculture.

Annual total wet-day precipitation (PRCPTOT) will decrease in autumn from 62.32 mm to 58.32 mm, while it will increase during other seasons. Annual region-averaged of PRCPTOT will increase by 2.92% from 61.23 mm to 63.02 mm. Maximum 5-day precipitation total (Rx5day) and number of very heavy rainy days (R20mm) will decrease in annual, however, those two indices will show positive trend in summer. PRCPTOT, Rx5day and R20mm are the indicators that are important for the intensity of precipitation. Therefore, rising in those indices, will lead the received precipitation to be more intense and especially increasing of these indices in summer is expected to cause unexpected extreme precipitation events. Consecutive dry days (CDD) will be decreasing in winter by -20.88% by the effect of increasing trend of precipitation in this season. While CDD index will be decreasing by -19.08%, consecutive wet days (CWD) will increase over the Aegean and Mediterranean coasts by 72.08% during summer season. The increase in CDD and CWD supports that the summer season will be wetter than it was before. Total annual precipitation from heavy rainy days (R95p) will be increasing by 10.44% from 156.97 mm to 173.36 mm. Moreover, the increase in R95p will increase the contribution from very wet days (R95pTOT).

Changes in temperature indices of the study area have been found consistent with the rising temperature through the region. Cold spell duration index (CSDI) is projected to strongly decrease over the region, while warm spell duration index

(WSDI) will be increasing significantly. The change in duration indicators (CSDI and WSDI) is likely to cause the emergence of longer heat-waves over the region. Growing season length (GSL) index will be increasing across the region by the middle of the century. A longer growing season means that the demand on the water supply will increase (WEB20). Daily temperature range (DTR) is expected to increase in the interiors of the Aegean and the Mediterranean and if the range is large, atmosphere becomes dry with little clouds (WEB21). Based on the analyses, summer days (SU25) and tropical nights (TR20) will be significantly increasing and this result supports the study of Sensoy et al. (2007). Frost days (FD) is projected to decrease over the interior parts of the study area and there will not be any trend observed in coastal areas. The frost-free season may be important for determining the growing season of vegetation (WEB22). Ice days (ID), the number of days when maximum temperature is below 0°C, will not be showing any trend over the coastal areas in annual, but there will be decreasing trend in the interiors in winter. For all seasons, the amount of hot days (TX90) and the amount of hot nights (TN90) will increase by the effect of warming, while the amount of cool days (TX10) and the amount of cold nights (TN10) will be decreasing. Percentile-based indicators (TX10, TX90, TN10, TN90) help us to evaluate the development of extreme events (López-Díaz et al., 2013). Therefore, the changes found in those indices indicate that occurrence and duration of heat stresses and warm waves are likely to increase. Moreover, all absolute indicators (TN_n, TN_x, TX_n and TX_x) are expected to increase across the study area as well since they are directly related with increasing in the daily maximum and minimum temperature.



CHAPTER 5

SUMMARY AND CONCLUSION

Ensemble modeling approach has been used in this thesis to make future projections for precipitation, temperature and climate indices of the Mediterranean climate region of Turkey. Observation data has been compared with data derived from models with and without bias-correction to determine the best model within the ensembles. Spatial distributions of precipitation and temperature have been obtained by interpolation to show the pattern of the region. Thereafter, trends in precipitation, temperature and climate indices have been detected. Trends have been mapped to present the geographical distribution of them through the study area. Future projection has been made up to middle of 21st century using the high carbon emission scenario (RCP8.5).

Conclusions provided below can be drawn from the thesis:

- HadGEM2-ES – *RACMO22E* and CM5A-MR – *WRF331F* model couplings have been found suitable for the analyses conducted with daily precipitation and temperature data, respectively.
- Major change have not been observed in the precipitation pattern. However, annual and seasonal precipitation is expected to increase across the region. While the coastal zones (the Aegean and the Mediterranean) will be experiencing drier season in spring and summer, they will be wetter in autumn and winter.
- Rising in the climate indicators related with intensity of precipitation will lead to the unexpected extreme events, especially during summer season. Significant increases in these events are expected to be seen especially in the Aegean region by the mid of the century.

- The changes found in climate indices related with temperature indicate that occurrence and duration of heat stresses and warm waves are likely to increase.

The results of the analyses conducted within this thesis show consistency with the other Mediterranean climate studies in the literature. In conclusion, there will be warming across the region, particularly in coastal areas. Moreover, annual precipitation amount is expected to increase within the mid of the century. However, it should be noted that under the same scenario condition the study area is expected to experience with warm and dry tendency by the end of the century according to the same model results. These results have considerable importance in terms of hydrological systems, forestry and agriculture. It should be noticed that climate change studies are crucial for adapting to the changes and avoiding the harmful influences of it.

While this thesis has been conducted the period of the middle of 21st century with respect to the future projections, it will be senseful for other researchers to carry out an analysis for the period of the end of 21st century, thereby the precipitation analyses together with its climate indices will be able to diversified and the period will be able to extended which enables to make more accurate and complete assessments within time period covering all century.

REFERENCES

- Adloff, F., Somot, S., Sevault, F., Jordà, G., Aznar, R., Déqué, M., Herrmann, M., Marcos, M., Dubois, C., Padorno, E., Alvarez-Fanjul, E., & Gomis, D. (2015). Mediterranean Sea response to climate change in an ensemble of twenty first century scenarios. *Climate Dynamics*, 45(9–10), 2775–2802.
<https://doi.org/10.1007/s00382-015-2507-3>
- Ahlgren, P., Jarneving, B., & Rousseau, R. (2003). Requirements for a cocitation similarity measure, with special reference to Pearson's correlation coefficient. *Journal of the American Society for Information Science and Technology*, 54(6), 550–560. <https://doi.org/10.1002/asi.10242>
- Alexander, L., & Herold, N. (2016). *ClimPACT2. Indices and software. A document prepared on behalf of The Commission for Climatology (CCI) Expert Team on Sector-Specific Climate Indices (ET-SCI). February*, 46.
- Alexander, L. V., Zhang, X., Peterson, T. C., Caesar, J., Gleason, B., Klein Tank, A. M. G., Haylock, M., Collins, D., Trewin, B., Rahimzadeh, F., Tagipour, A., Rupa Kumar, K., Revadekar, J., Griffiths, G., Vincent, L., Stephenson, D. B., Burn, J., Aguilar, E., Brunet, M., ... Vazquez-Aguirre, J. L. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research Atmospheres*, 111(5), 1–22.
<https://doi.org/10.1029/2005JD006290>
- Altın, T. B., Barak, B., & Altın, B. N. (2012). Change in Precipitation and Temperature Amounts over Three Decades in Central Anatolia, Turkey. *Atmospheric and Climate Sciences*, 02(01), 107–125.
<https://doi.org/10.4236/acs.2012.21013>
- Dabanlı, İ., Mishra, A. K., & Şen, Z. (2017). Long-term spatio-temporal drought variability in Turkey. *Journal of Hydrology*, 552(July), 779–792.
<https://doi.org/10.1016/j.jhydrol.2017.07.038>

- Dogru, A. O., Keskin, M., Ozdogu, K., Iliev, N., Ulugtekin, N., Balcik, F. B., Goksel, C., & Sozen, S. (2011). Meteorolojik Verilerin Değerlendirilmesi ve Sunulması için Enterpolasyon Yöntemlerinin Karşılaştırılması. *TMMOB Coğrafi Bilgi Sistemleri Kongresi, October*.
- Donat, M. G., Alexander, L. V., Yang, H., Durre, I., Vose, R., & Caesar, J. (2013). Global land-based datasets for monitoring climatic extremes. *Bulletin of the American Meteorological Society*, 94(7), 997–1006.
<https://doi.org/10.1175/BAMS-D-12-00109.1>
- Donat, M. G., Alexander, L. V., Yang, H., Durre, I., Vose, R., Dunn, R. J. H., Willett, K. M., Aguilar, E., Brunet, M., Caesar, J., Hewitson, B., Jack, C., Klein Tank, A. M. G., Kruger, A. C., Marengo, J., Peterson, T. C., Renom, M., Oria Rojas, C., Rusticucci, M., ... Kitching, S. (2013). Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset. *Journal of Geophysical Research Atmospheres*, 118(5), 2098–2118. <https://doi.org/10.1002/jgrd.50150>
- dos Santos, C. A. C., Neale, C. M. U., Rao, T. V. R., & da Silva, B. B. (2011). Trends in indices for extremes in daily temperature and precipitation over Utah, USA. *International Journal of Climatology*, 31(12), 1813–1822.
<https://doi.org/10.1002/joc.2205>
- Erlat, E., & Türkeş, M. (2013). Observed changes and trends in numbers of summer and tropical days, and the 2010 hot summer in Turkey. *International Journal of Climatology*, 33(8), 1898–1908. <https://doi.org/10.1002/joc.3556>
- Fallah-Ghalhari, G., Shakeri, F., & Dadashi-Roudbari, A. (2019). Impacts of climate changes on the maximum and minimum temperature in Iran. *Theoretical and Applied Climatology*, 138(3–4), 1539–1562.
<https://doi.org/10.1007/s00704-019-02906-9>
- Folland, C. K., Karl, T. R., & Jim Salinger, M. (2002). Observed climate variability and change. *Weather*, 57(8), 269–278.

<https://doi.org/10.1256/004316502320517353>

Frich, P., Alexander, L. V., Della-Marta, P., Gleason, B., Haylock, M., Tank Klein, 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>

Giorgi, F. (2006). Climate change hot-spots. *Geophysical Research Letters*, 33(8), 1–4. <https://doi.org/10.1029/2006GL025734>

Giorgi, F., & Lionello, P. (2008). Climate change projections for the Mediterranean region. *Global and Planetary Change*, 63(2–3), 90–104. <https://doi.org/10.1016/j.gloplacha.2007.09.005>

Gleckler, P. J., Taylor, K. E., & Doutriaux, C. (2008). Performance metrics for climate models. *Journal of Geophysical Research Atmospheres*, 113(6), 1–20. <https://doi.org/10.1029/2007JD008972>

Gocic, M., & Trajkovic, S. (2013). Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. *Global and Planetary Change*, 100, 172–182. <https://doi.org/10.1016/j.gloplacha.2012.10.014>

Hertig, E., & Jacobeit, J. (2008). Downscaling future climate change: Temperature scenarios for the Mediterranean area. *Global and Planetary Change*, 63(2–3), 127–131. <https://doi.org/10.1016/j.gloplacha.2007.09.003>

Houghton, J. T., Meira Filho, L. G., Callander, B. A., Harris, N., Kattenberg, A., & Maskell, K. (1996). Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. In *Cambridge: Cambridge University Press*. <https://doi.org/10.4324/9780203876213.ch1>

Ilker, A., Terzi, Ö., & Sener, E. (2019). Yağışın Alansal Dağılımının Haritalandırılmasında Enterpolasyon Yöntemlerinin Karşılaştırılması:

- Akdeniz Bölgesi Örneği. *Teknik Dergi*, 9213–9219.
<https://doi.org/10.18400/tekderg.334186>
- Keggenhoff, I., Elizbarashvili, M., Amiri-Farahani, A., & King, L. (2014). Trends in daily temperature and precipitation extremes over Georgia, 1971–2010. *Weather and Climate Extremes*, 4(August), 75–85.
<https://doi.org/10.1016/j.wace.2014.05.001>
- Kim, G. U., Seo, K. H., & Chen, D. (2019). Climate change over the Mediterranean and current destruction of marine ecosystem. In *Scientific Reports* (Vol. 9, Issue 1). Springer US. <https://doi.org/10.1038/s41598-019-55303-7>
- Koudahe, K., Kayode, A. J., Samson, A. O., Adebola, A. A., & Djaman, K. (2017). Trend Analysis in Standardized Precipitation Index and Standardized Anomaly Index in the Context of Climate Change in Southern Togo. *Atmospheric and Climate Sciences*, 07(04), 401–423.
<https://doi.org/10.4236/acs.2017.74030>
- Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., El Maayar, M., Giannakopoulos, C., Hannides, C., Lange, M. A., Tanarhte, M., Tyrlis, E., & Xoplaki, E. (2012). Climate change and impacts in the Eastern Mediterranean and the Middle East. *Climatic Change*, 114(3–4), 667–687.
<https://doi.org/10.1007/s10584-012-0418-4>
- Lestari, S., King, A., Vincent, C., Karoly, D., & Protat, A. (2019). Seasonal dependence of rainfall extremes in and around Jakarta, Indonesia. *Weather and Climate Extremes*, 24(February), 100202.
<https://doi.org/10.1016/j.wace.2019.100202>
- Lionello, P., Abrantes, F., Congedi, L., Dulac, F., Gacic, M., Gomis, D., Goodess, C., Hoff, H., Kutiel, H., Luterbacher, J., Planton, S., Reale, M., Schröder, K., Vittoria Struglia, M., Toreti, A., Tsimplis, M., Ulbrich, U., & Xoplaki, E. (2012). Introduction: Mediterranean climate-background information. In *The Climate of the Mediterranean Region*. <https://doi.org/10.1016/B978-0-12->

- López-Díaz, F., Conde, C., & Sánchez, O. (2013). Analysis of indices of extreme temperature events at Apizaco, Tlaxcala, Mexico: 1952-2003. *Atmosfera*, 26(3), 349–358. [https://doi.org/10.1016/S0187-6236\(13\)71081-6](https://doi.org/10.1016/S0187-6236(13)71081-6)
- Mann, H. B. (1945). Non-Parametric Test Against Trend. *Econometrica*, 13(3), 245–259.
http://www.economist.com/node/18330371?story%7B_%7Ddid=18330371
- Nikulin, G., & Legutke, S. (2016). *Data Reference Syntax (DRS) for bias-adjusted CORDEX simulations*. http://is-enes-data.github.io/CORDEX_adjust_drs.pdf
- Ozturk, T., Turp, M. T., Türkeş, M., & Kurnaz, M. L. (2018). Future projections of temperature and precipitation climatology for CORDEX-MENA domain using RegCM4.4. *Atmospheric Research*, 206(October 2017), 87–107.
<https://doi.org/10.1016/j.atmosres.2018.02.009>
- Pereira, S. C., Marta-Almeida, M., Carvalho, A. C., & Rocha, A. (2019). *Extreme Precipitation Events under Climate Change in the Iberian Peninsula. August*.
<https://doi.org/10.1002/joc.6269>
- Pincus, R., Batstone, C. P., Patrick Hofmann, R. J., Taylor, K. E., & Glecker, P. J. (2008). Evaluating the present-day simulation of clouds, precipitation, and radiation in climate models. *Journal of Geophysical Research Atmospheres*, 113(14), 1–10. <https://doi.org/10.1029/2007JD009334>
- Riahi, K., Rao, S., Krey, V., Cho, C., Chirkov, V., Fischer, G., Kindermann, G., Nakicenovic, N., & Rafaj, P. (2011). RCP 8.5-A scenario of comparatively high greenhouse gas emissions. *Climatic Change*, 109(1), 33–57.
<https://doi.org/10.1007/s10584-011-0149-y>
- Schaller, N., Mahlstein, I., Cermak, J., & Knutti, R. (2011). Analyzing precipitation projections: A comparison of different approaches to climate model evaluation. *Journal of Geophysical Research Atmospheres*, 116(10), 1–14.

<https://doi.org/10.1029/2010JD014963>

- Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall ' s Tau. *Journal of the American Statistical Association*, 63(324), 1379–1389.
- Sensoy, S., Demircan, M., & Alan, I. (2007). Trends in Turkey climate indices from 1971 to 2004 and future projection. *Geophysical Research Abstracts*, 9(May), 2.
- Sensoy, S., Demircan, M., Ulupinar, Y., & Balta, I. (2016). *Climate of Turkey. March*.
- Solomon, S., Qin, D., & Manning, M. (2007). *IPCC 4th Ass. Report: The Physical Science Basis (2007)*. <https://doi.org/10.1256/wea.58.04>
- Somot, S., Sevault, F., Déqué, M., & Crépon, M. (2008). 21st century climate change scenario for the Mediterranean using a coupled atmosphere-ocean regional climate model. *Global and Planetary Change*, 63(2–3), 112–126. <https://doi.org/10.1016/j.gloplacha.2007.10.003>
- Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M. M. B., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Vincent, P. M. (2013). *IPCC 5th Ass. Report: The Physical Science Basis (2013)*.
- Thiébaud, S. et al. (2016). The Mediterranean Region under Climate Change. In *The Mediterranean Region under Climate Change A Scientific Update*. (French National Alliance for Environmental Research.
- TSMS Research Dept. (2020). *State of the Climate in Turkey in 2019*.
- Türkeş, M. (1999). Vulnerability of Turkey to desertification with respect to precipitation and aridity conditions. *Turkish Journal of Engineering and Environmental Sciences*, 23(5), 363–380.
- Türkeş, M., & Erlat, E. (2003). Precipitation changes and variability in Turkey linked to the North Atlantic oscillation during the period 1930-2000.

International Journal of Climatology, 23(14), 1771–1796.

<https://doi.org/10.1002/joc.962>

Turp, M. T., Öztürk, T., Türkeş, M., & Kurnaz, M. L. (2015). Modeling of near future air temperature and precipitation climatology of Turkey and surrounding regions. *J. Black Sea/Mediterranean Environment*, 92(Special Issue), 89–92.

Xoplaki, E. (2002). Climate variability over the Mediterranean. In *Spring*.

Yilmaz, K. K., & Yazicigil, H. (2011). Potential Impacts of Climate Change on Turkish Water Resources: A Review. In *NATO Science for Peace and Security Series C: Environmental Security* (Vol. 3).

<https://doi.org/10.1007/978-94-007-1143-3>

Yucel, I., Güventürk, A., & Sen, O. L. (2015). Climate change impacts on snowmelt runoff for mountainous transboundary basins in eastern Turkey. *International Journal of Climatology*, 35(2), 215–228.

<https://doi.org/10.1002/joc.3974>

Zhang, X., Aguilar, E., Sensoy, S., Melkonyan, H., Tagiyeva, U., Ahmed, N., Kutaladze, N., Rahimzadeh, F., Taghipour, A., Hantosh, T. H., Albert, P., Semawi, M., Karam Ali, M., Said Al-Shabibi, M. H., Al-Oulan, Z., Zatari, T., Khelet, I. A. D., Hamoud, S., Sagir, R., ... Wallis, T. (2005). Trends in Middle East climate extreme indices from 1950 to 2003. *Journal of Geophysical Research Atmospheres*, 110(22), 1–12.

<https://doi.org/10.1029/2005JD006181>

Zhang, X., Alexander, L., Hegerl, G. C., Jones, P., Tank, A. K., Peterson, T. C., Trewin, B., & Zwiers, F. W. (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation data. *Wiley Interdisciplinary Reviews: Climate Change*, 2(6), 851–870.

<https://doi.org/10.1002/wcc.147>



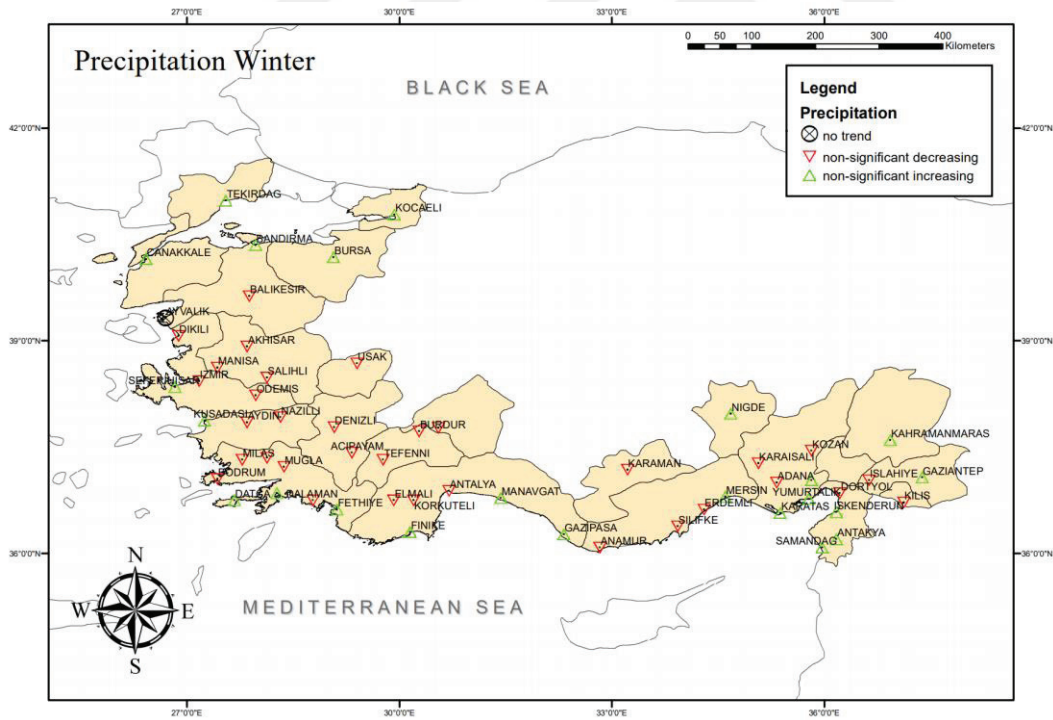
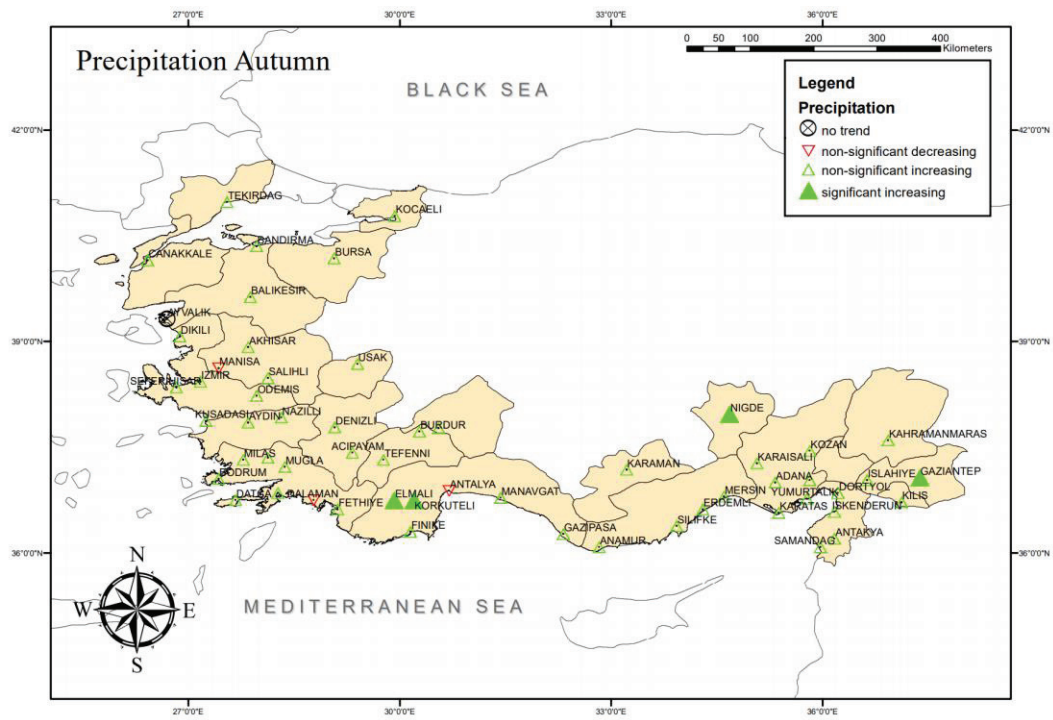


Figure 3.26. (cont'd)

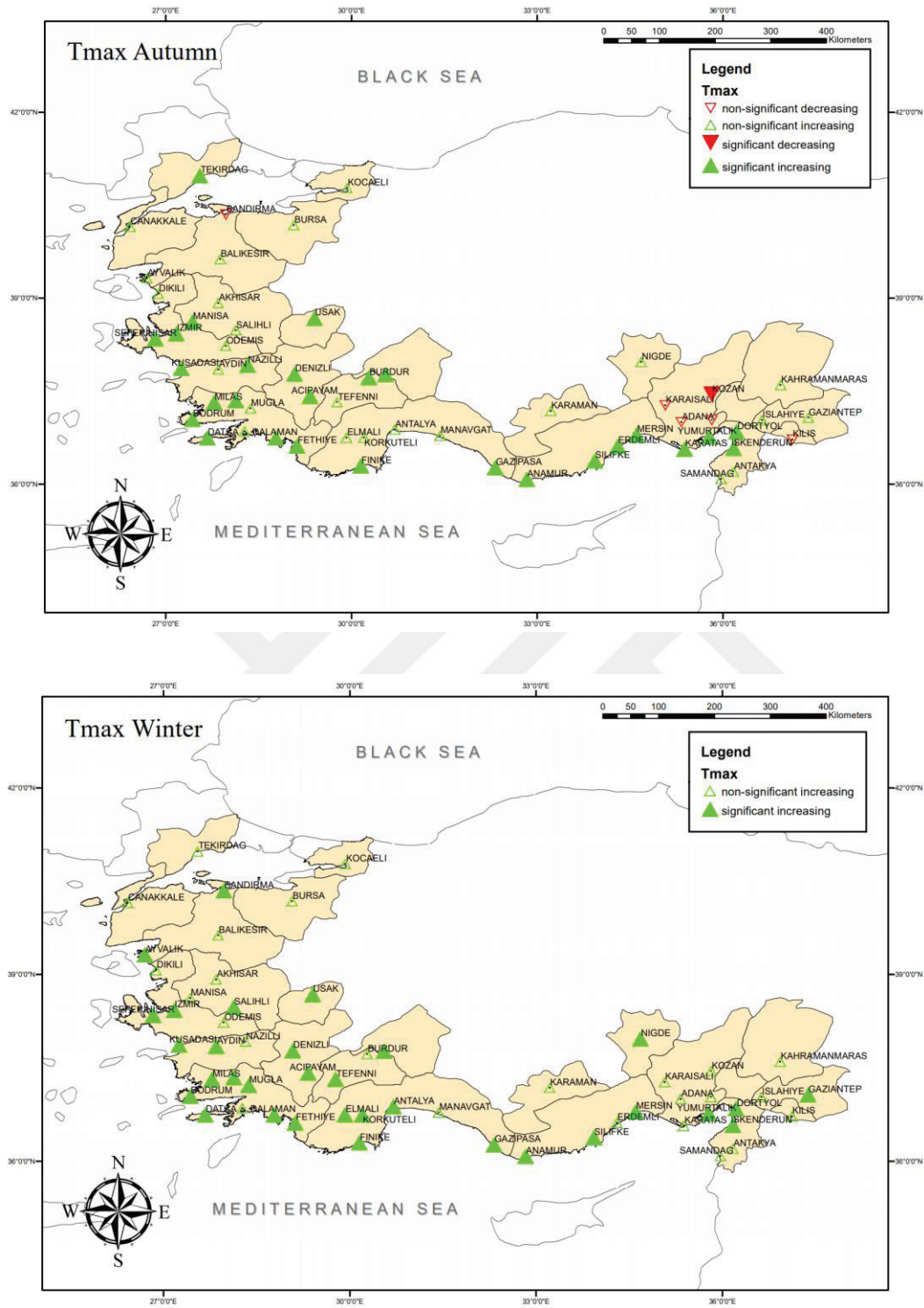


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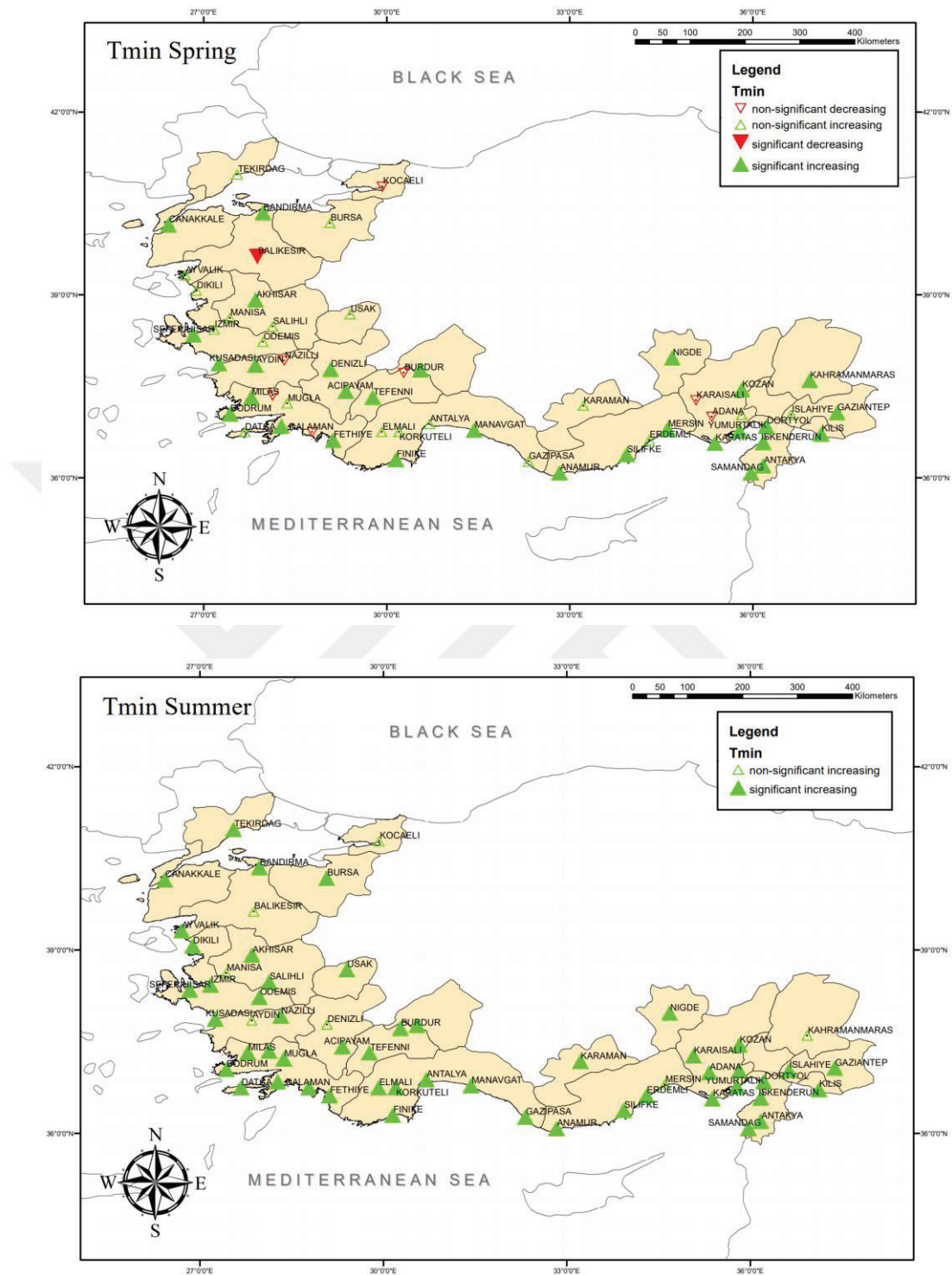


Figure 3.28. Spatial distributions of seasonal trends in minimum temperature of the region in the baseline period (1970-2011).

B. Seasonal Trend of Climate Indices in 1970-2011

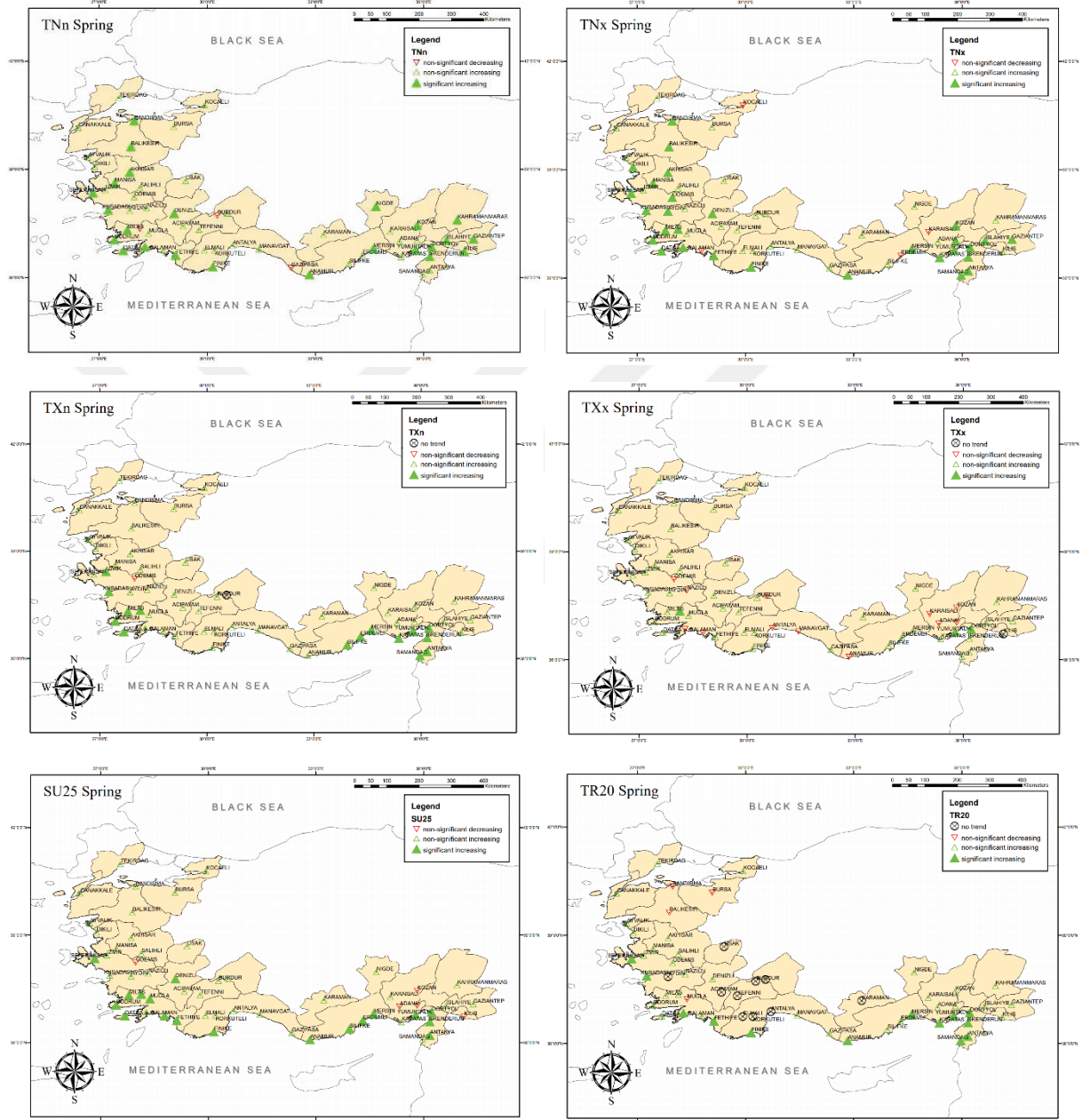


Figure 3.29. Spring season trends of TNn, TNx, TXn, TXx, SU25 and TR20 indicators in the baseline period 1970-2011.

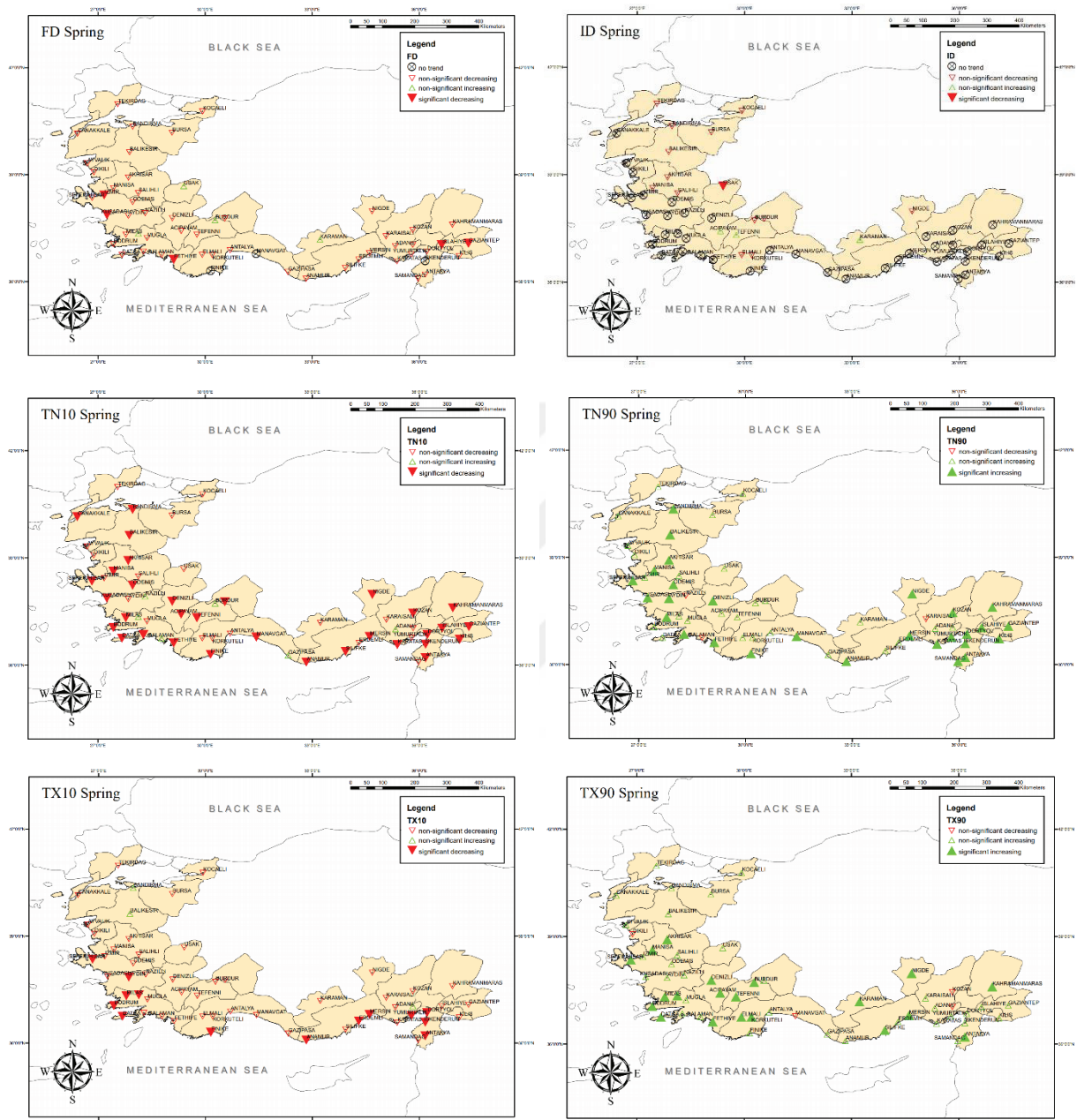


Figure 3.30. Spring season trends of FD, ID, TN10, TN90, TX10 and TX90 indicators in the baseline period 1970-2011.

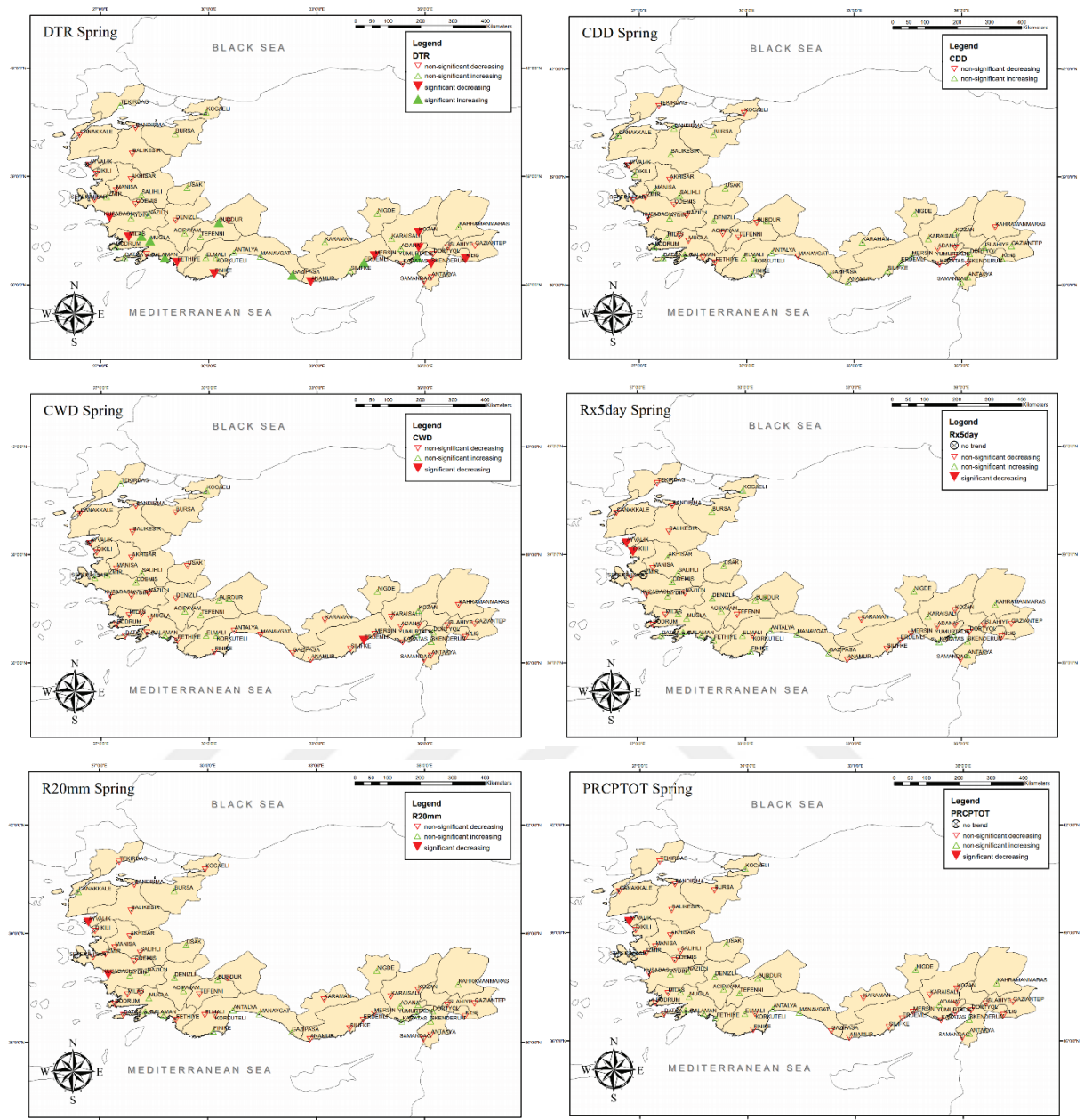


Figure 3.31. Spring season trends of DTR, CDD, CWD, Rx5day, R20mm and PRCPOT indicators in the baseline period 1970-2011.

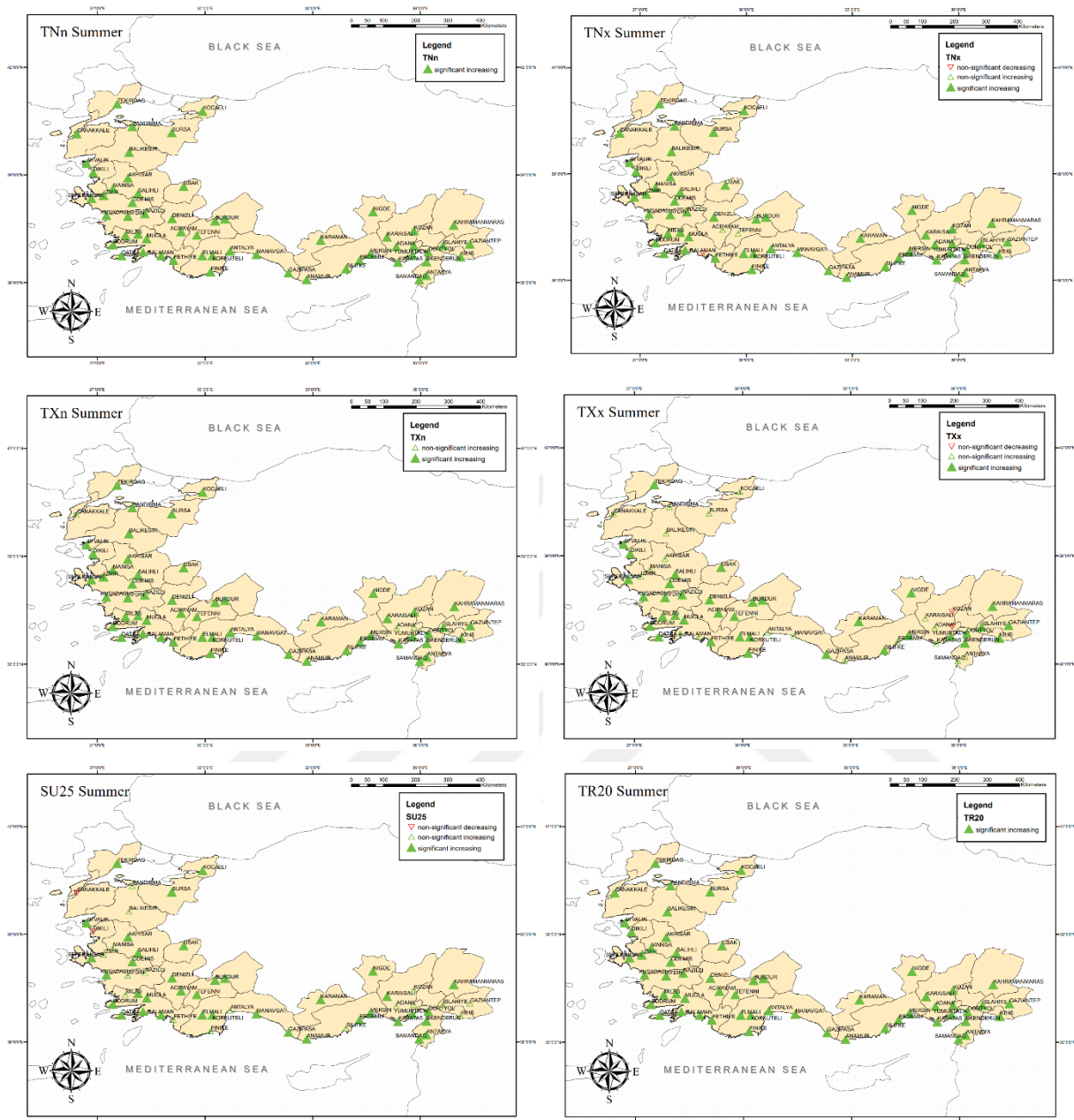


Figure 3.32. Summer season trends of TNn, TNx, TXn, TXx, SU25 and TR20 indicators in the baseline period 1970-2011.

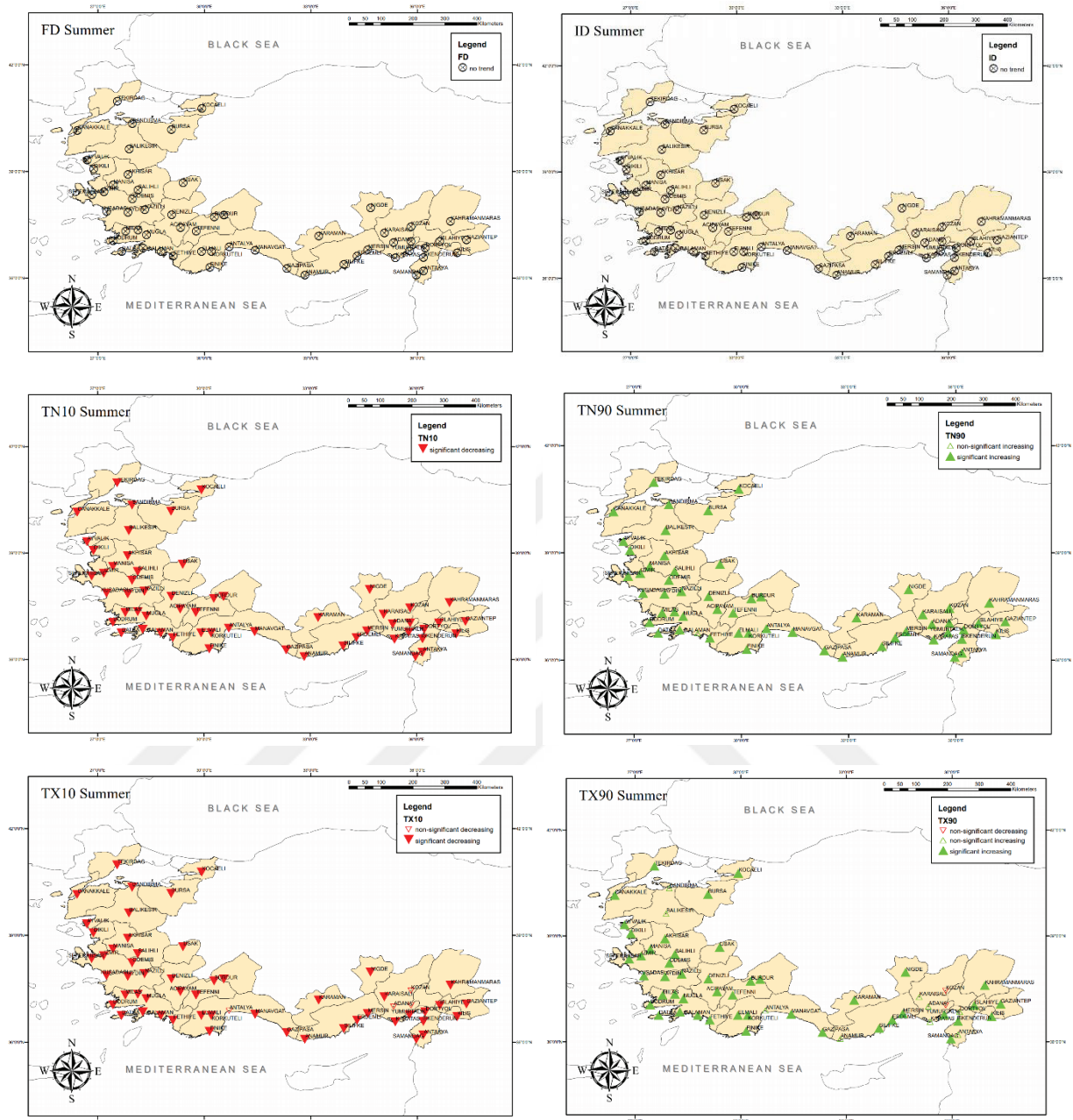


Figure 3.33. Summer season trends of FD, ID, TN10, TN90, TX10 and TX90 indicators in the baseline period 1970-2011.

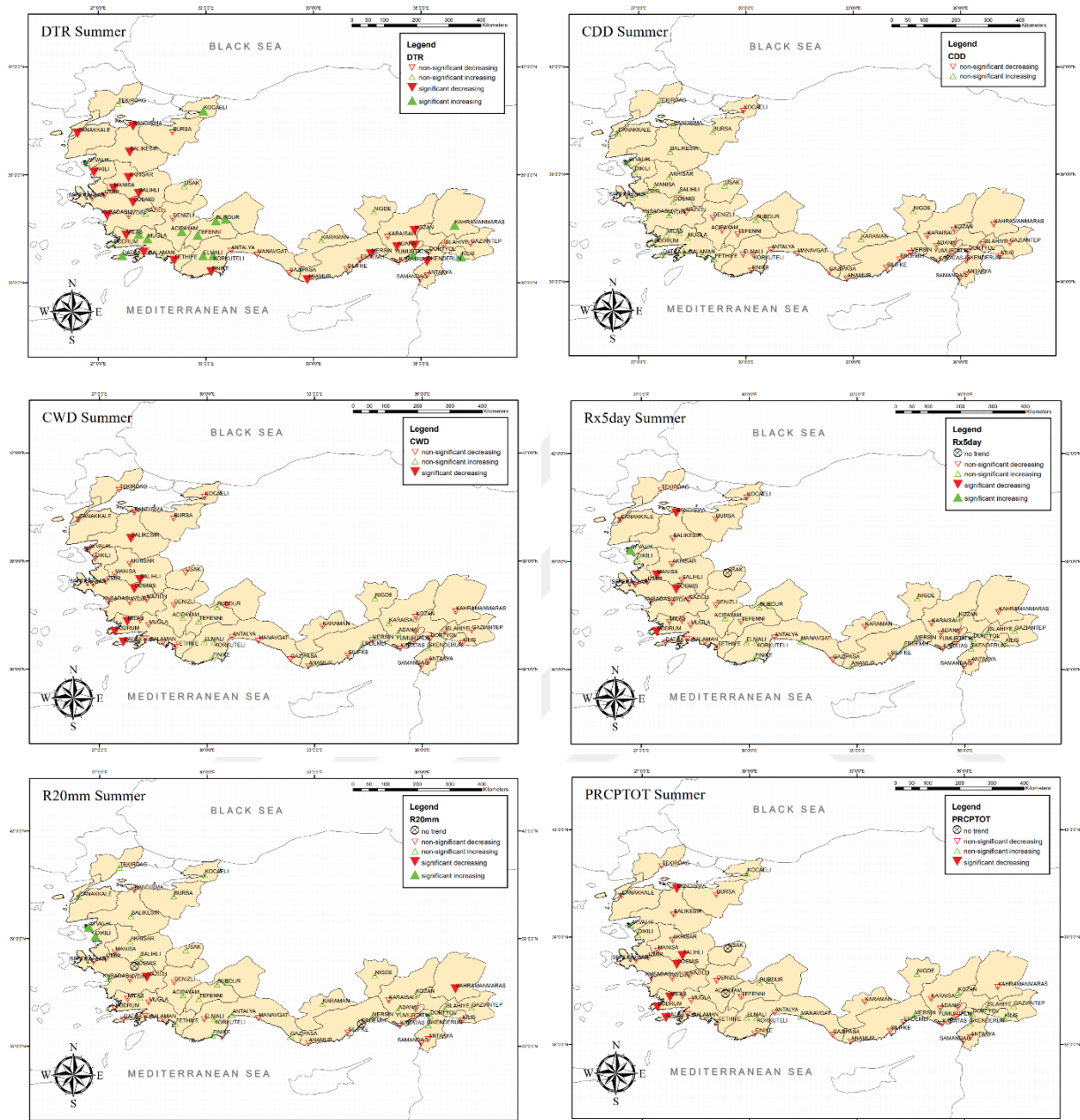


Figure 3.34. Summer season trends of DTR, CDD, CWD, Rx5day, R20mm and PRCPOT indicators in the baseline period 1970-2011.

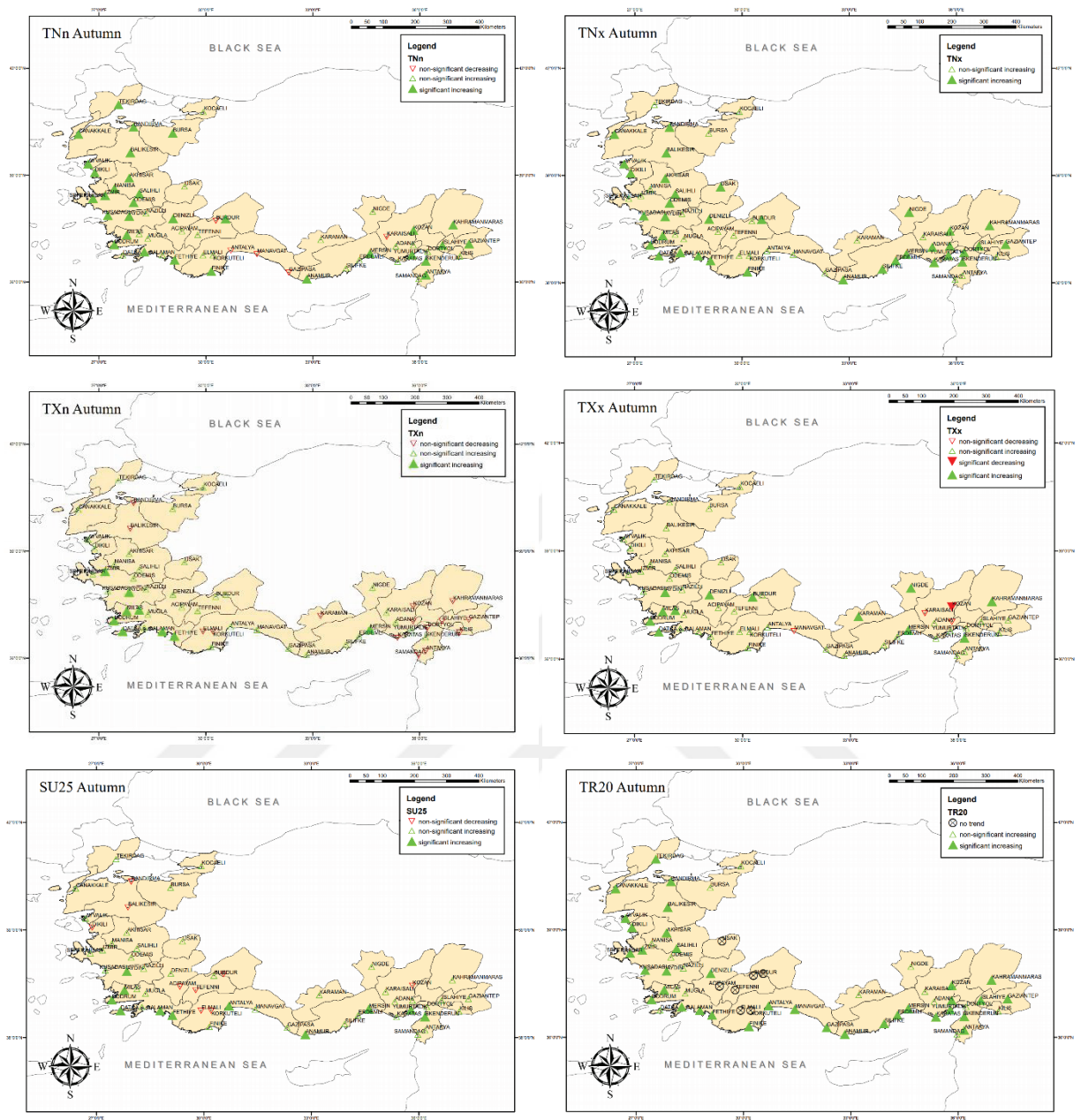


Figure 3.35. Autumn season trends of TNn, TNx, TXn, TXx, SU25 and TR20 indicators in the baseline period 1970-2011.

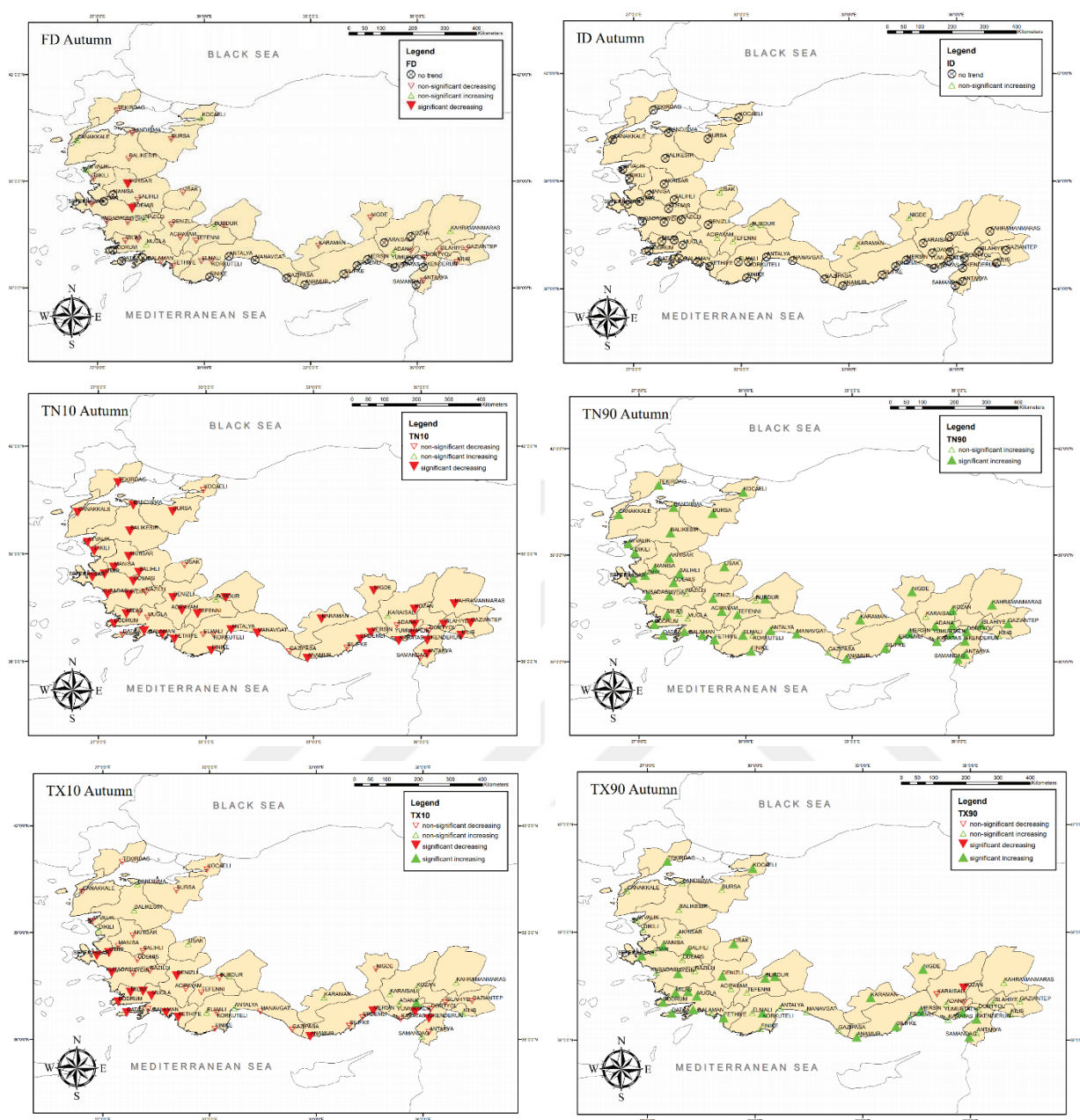


Figure 3.36. Autumn season trends of FD, ID, TN10, TN90, TX10 and TX90 indicators in the baseline period 1970-2011.

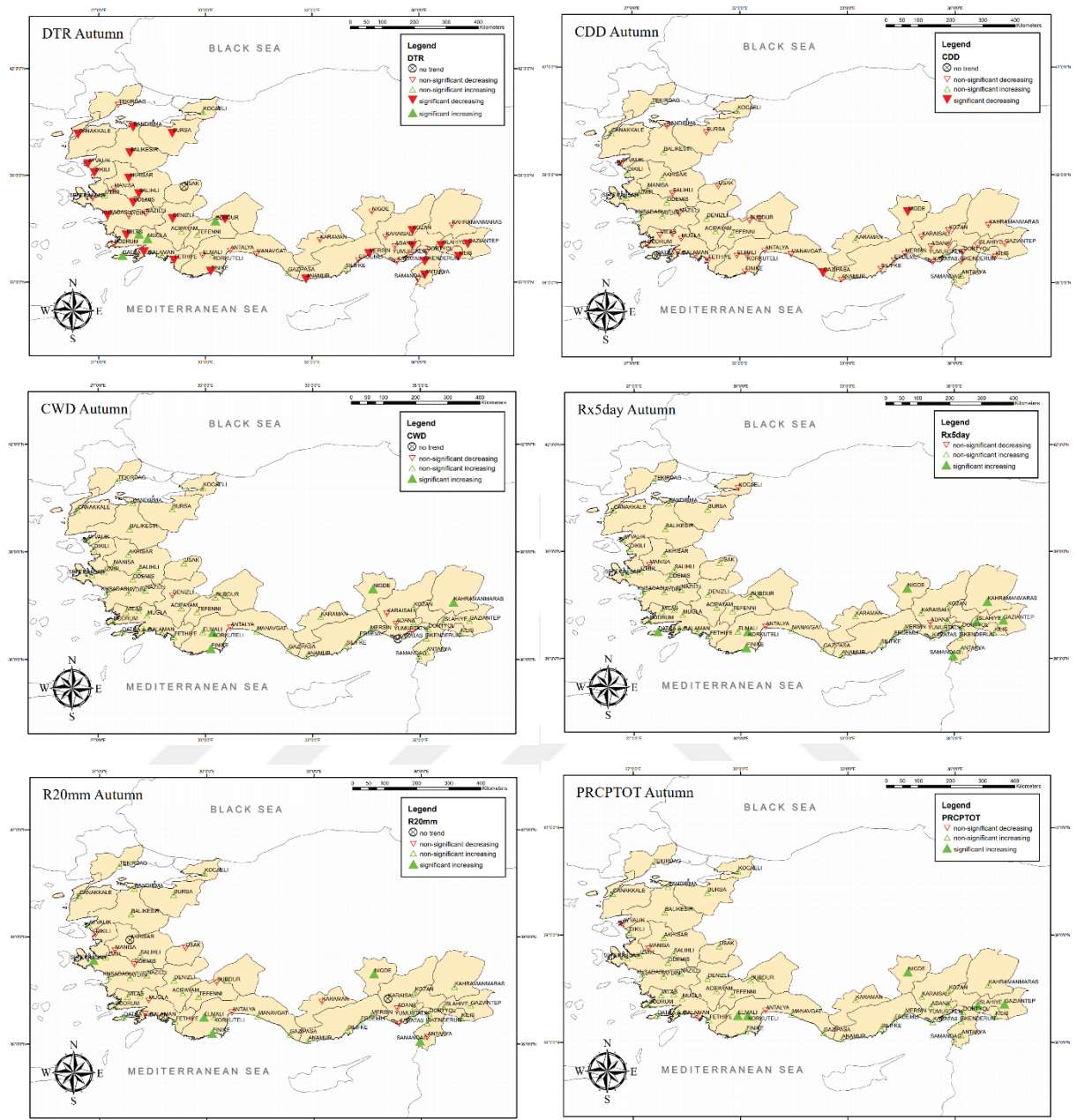


Figure 3.37. Autumn season trends of DTR, CDD, CWD, Rx5day, R20mm and PRCPTOT indicators in the baseline period 1970-2011.

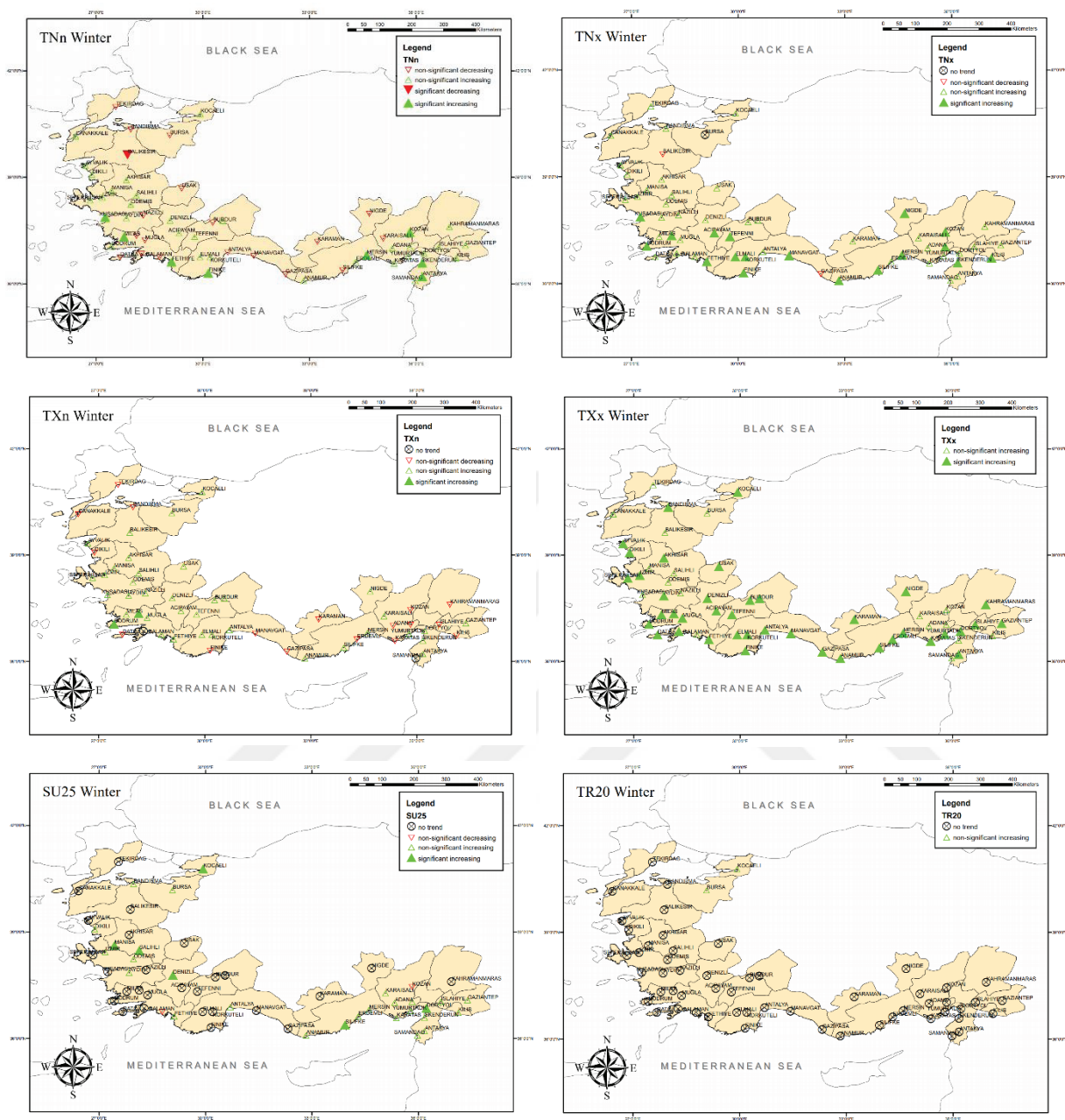


Figure 3.38. Winter season trends of TNn, TNx, TXn, TXx, SU25 and TR20 indicators in the baseline period 1970-2011.

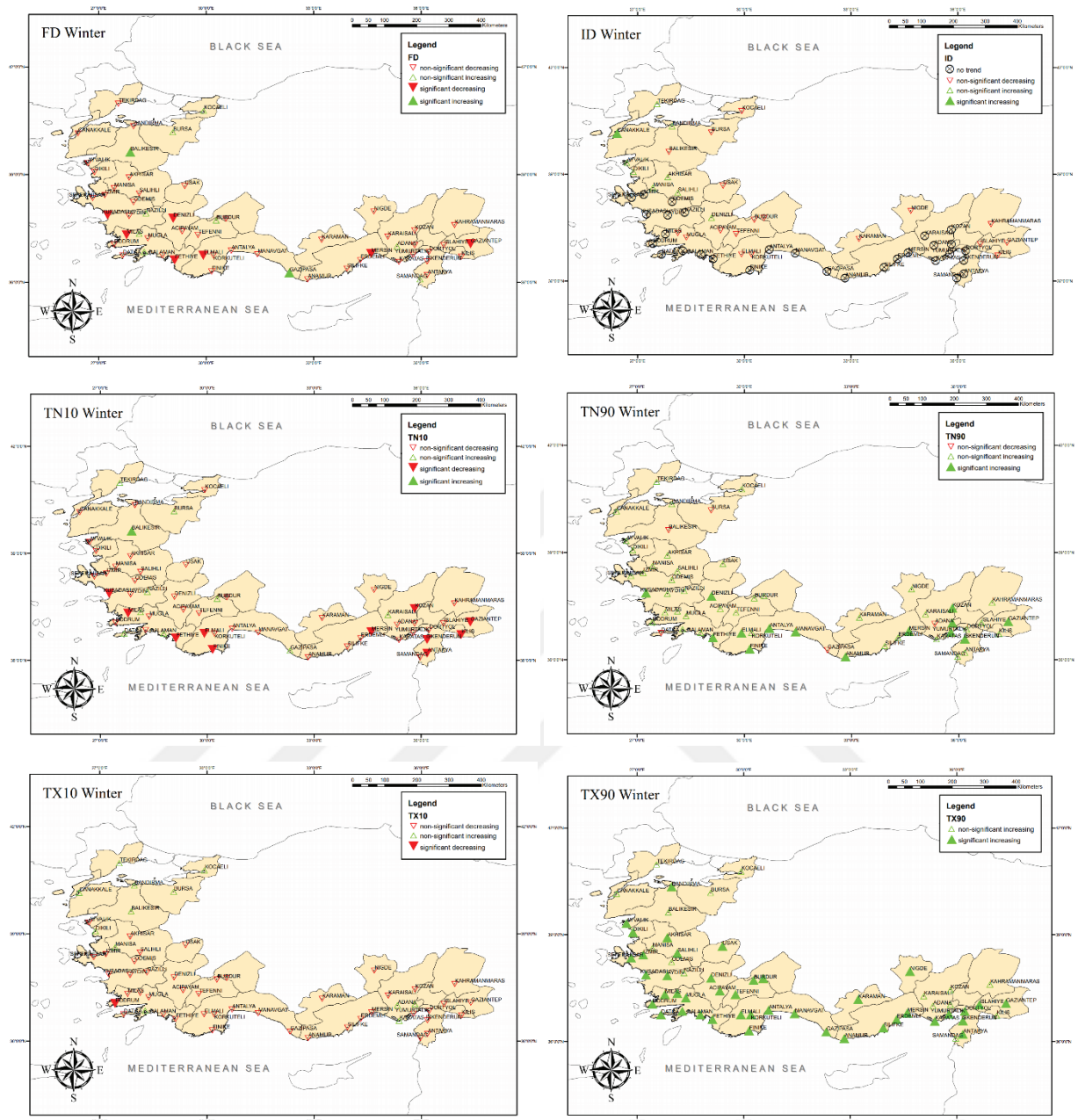


Figure 3.39. Winter season trends of FD, ID, TN10, TN90, TX10 and TX90 indicators in the baseline period 1970-2011.

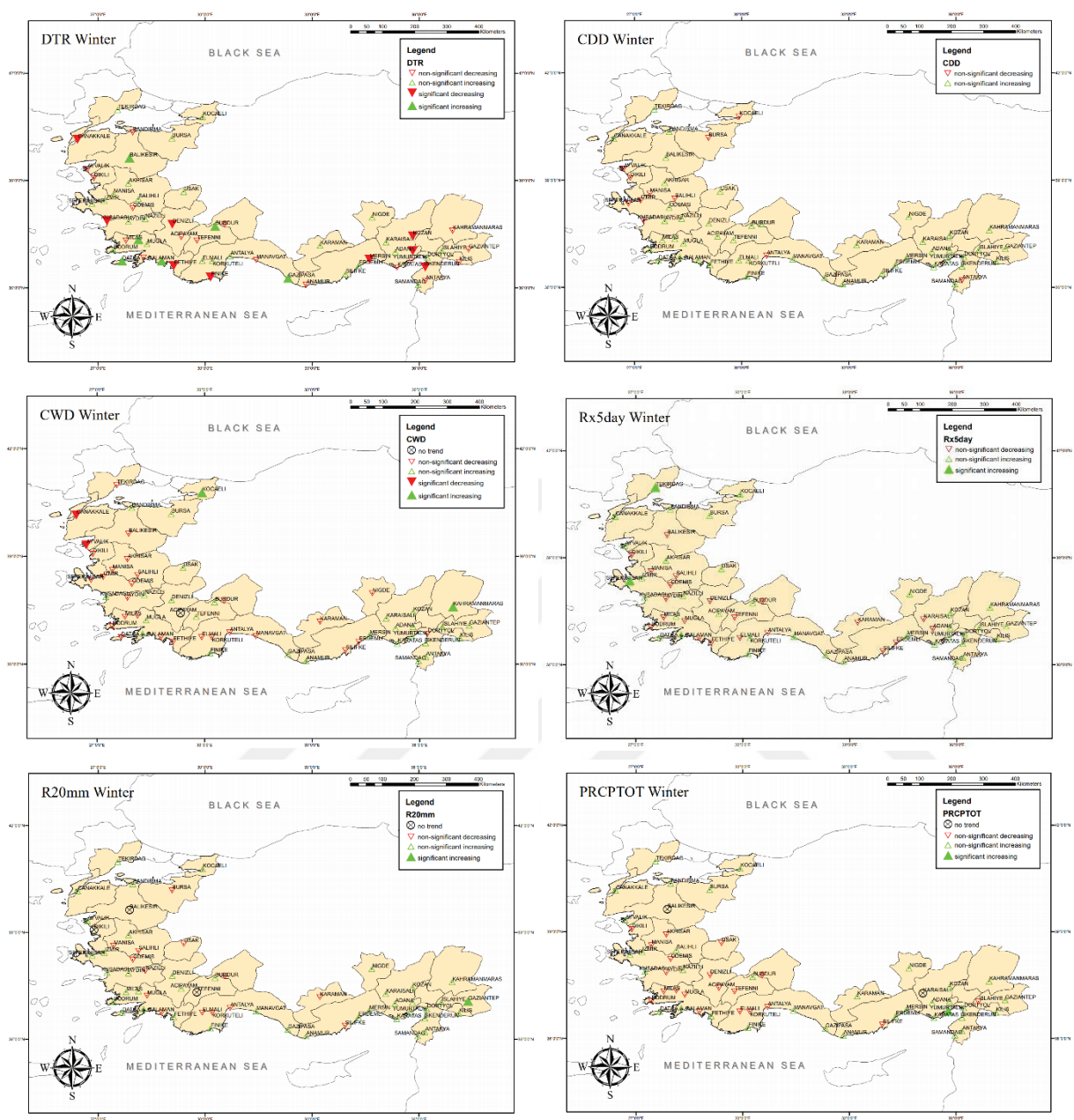


Figure 3.40. Winter season trends of DTR, CDD, CWD, Rx5day, R20mm and PRCPTOT indicators in the baseline period 1970-2011.

C. Seasonal Distributions of Precipitation and Temperature in 2011-2050

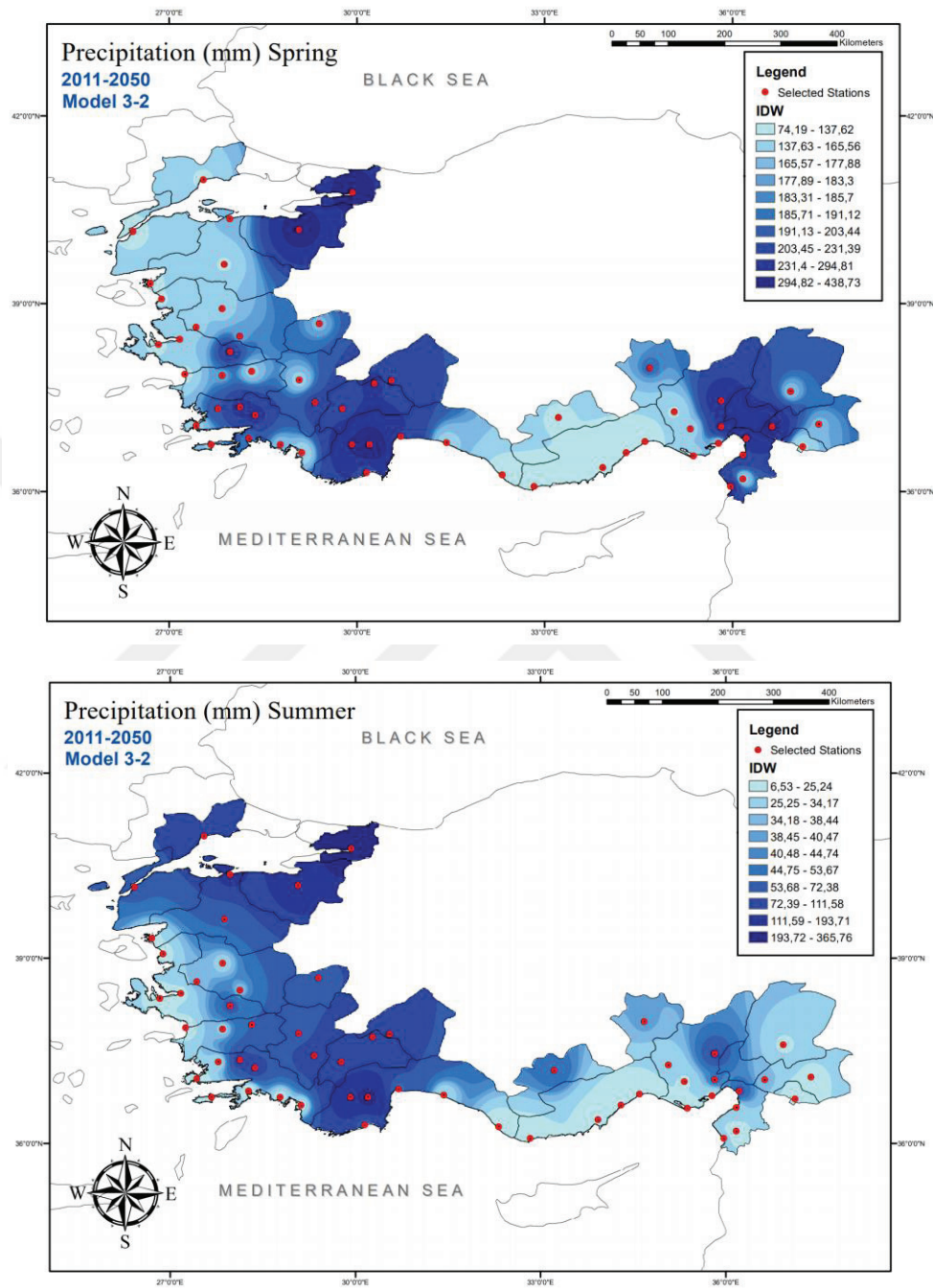


Figure 3.41. Seasonal precipitation distribution of the region in 2011-2050.

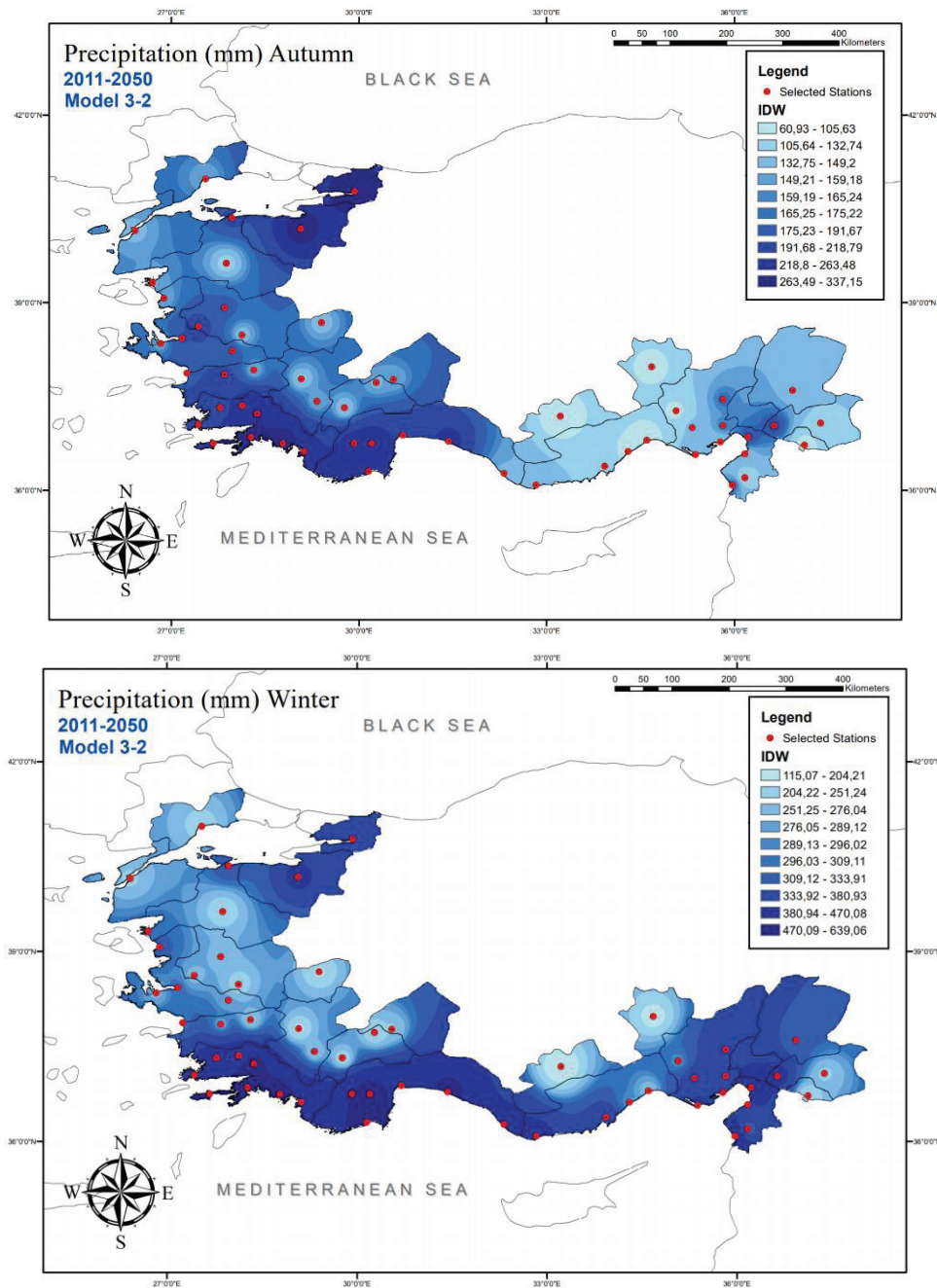


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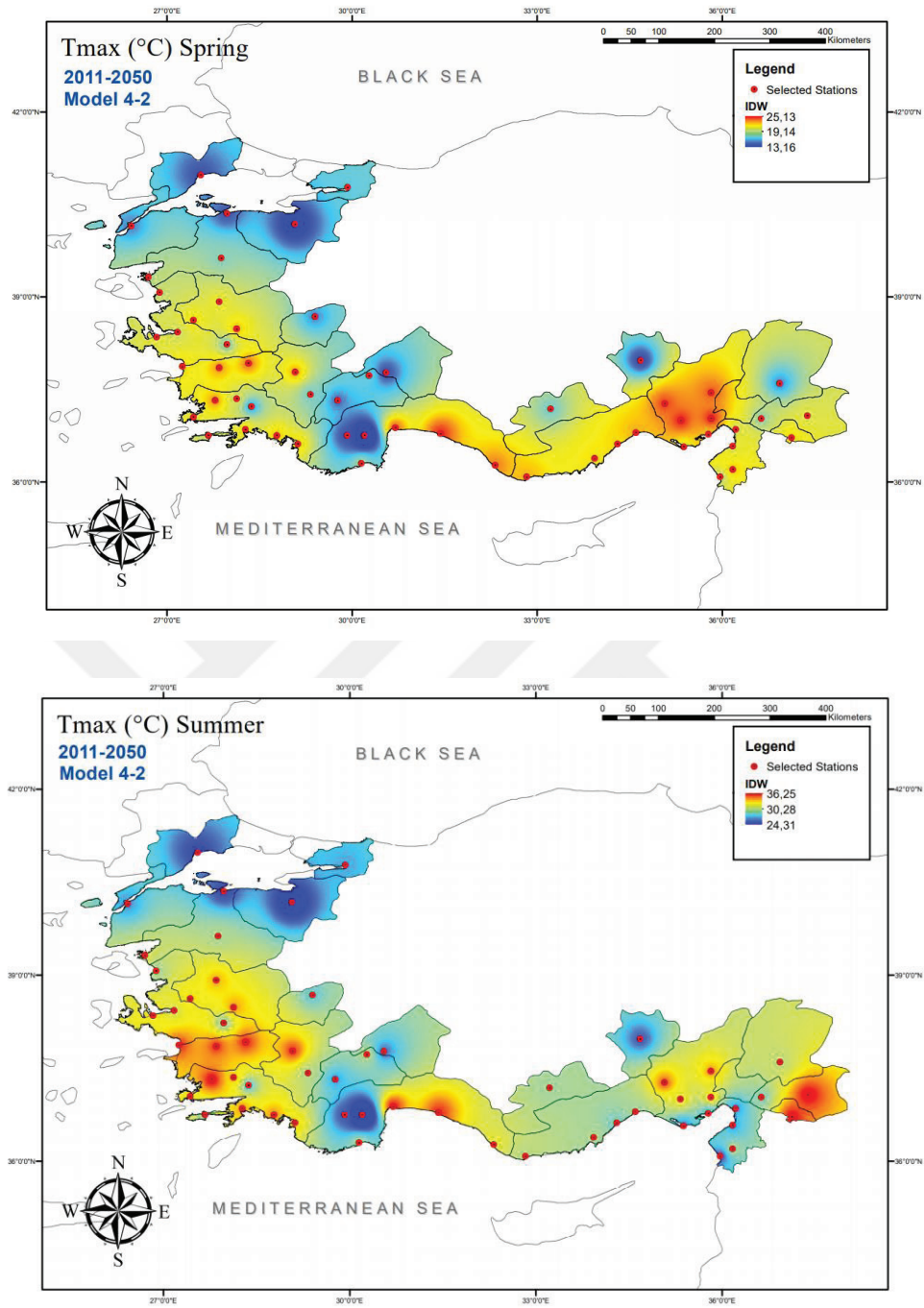


Figure 3.42. Seasonal maximum temperature distribution of the region in 2011-2050.

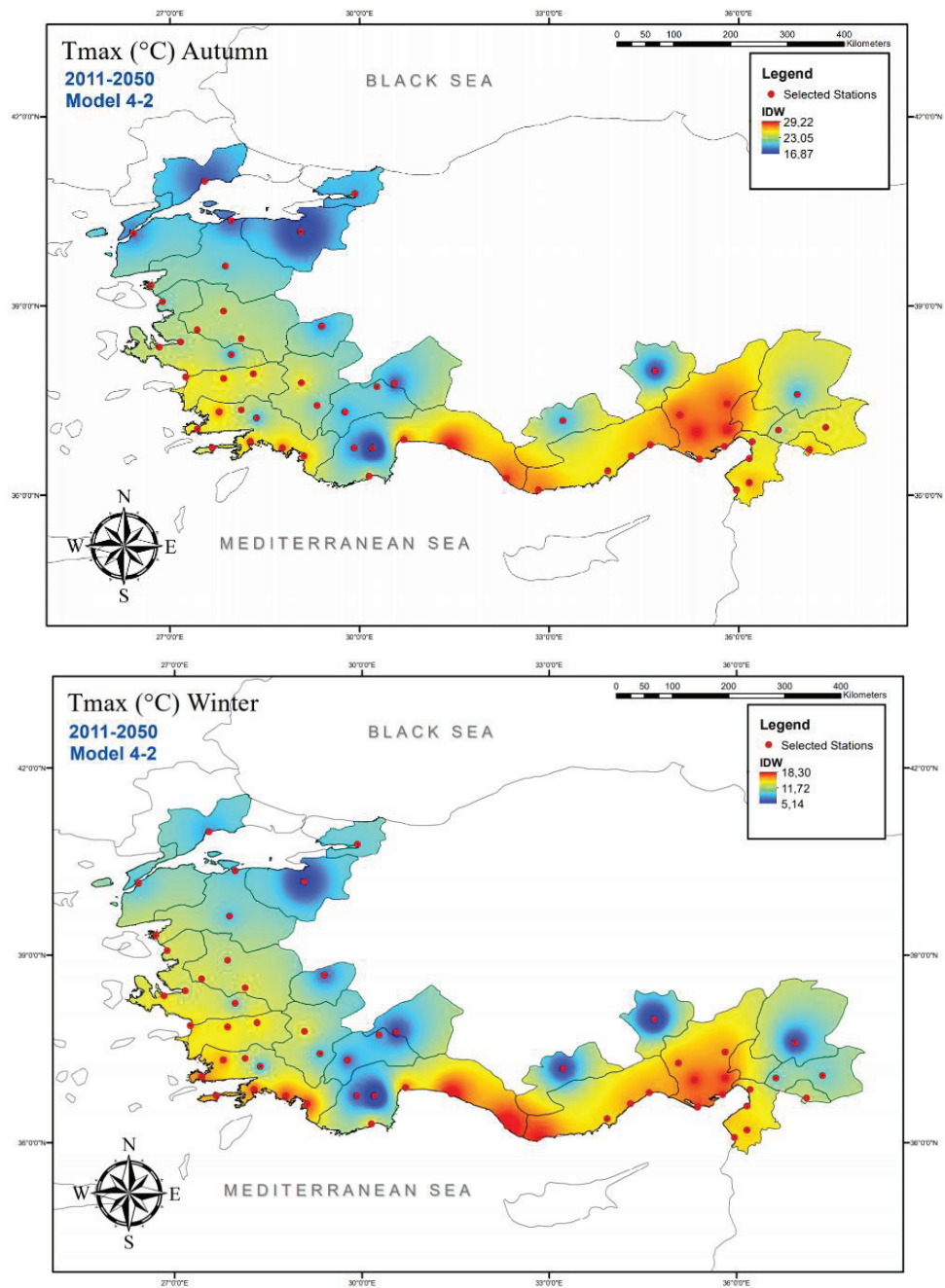


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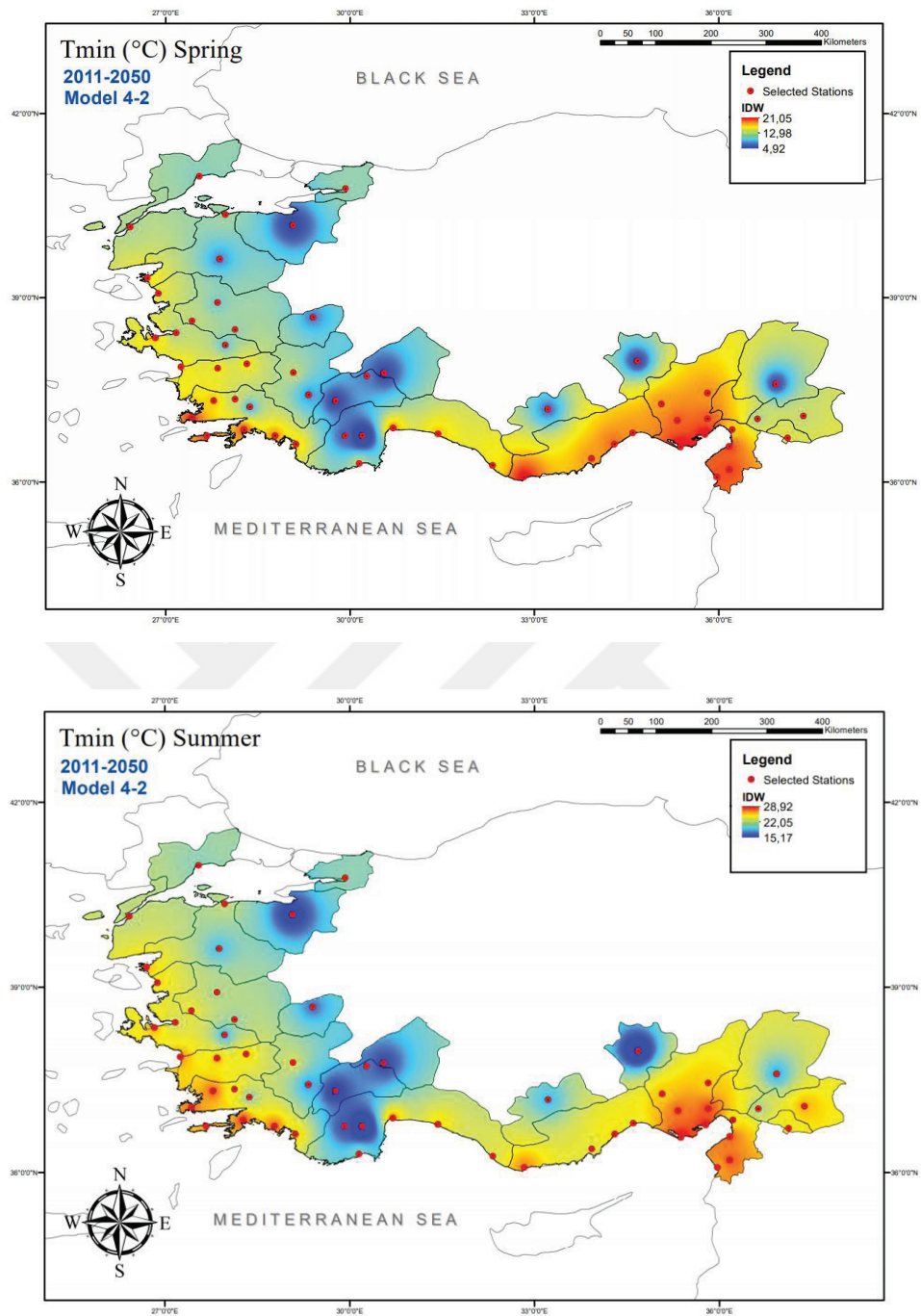


Figure 3.43. Seasonal minimum temperature distribution of the region in 2011-2050.

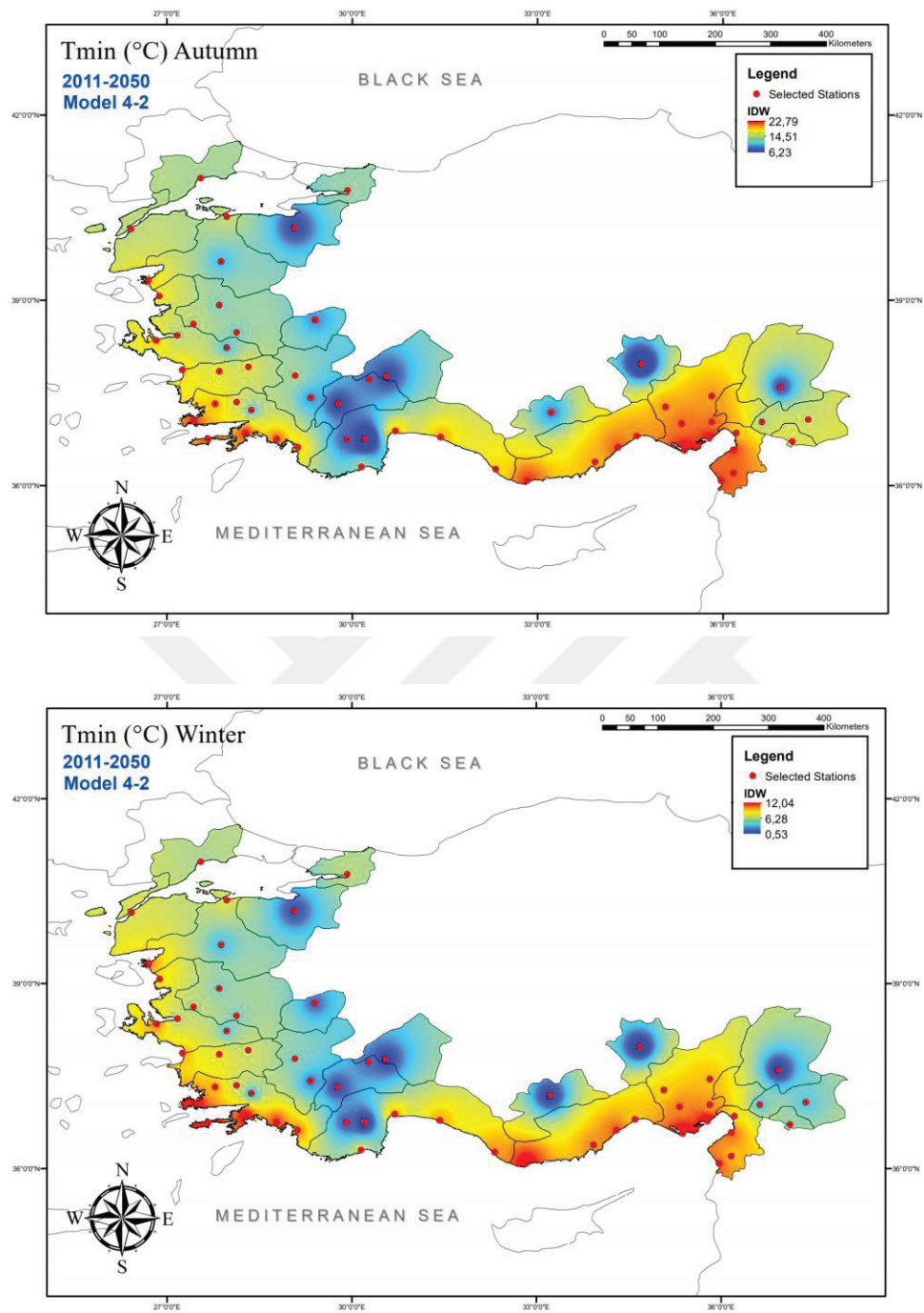


Figure 3.43. (cont'd)

D. Seasonal Trends in Precipitation and Temperature in 2011-2050

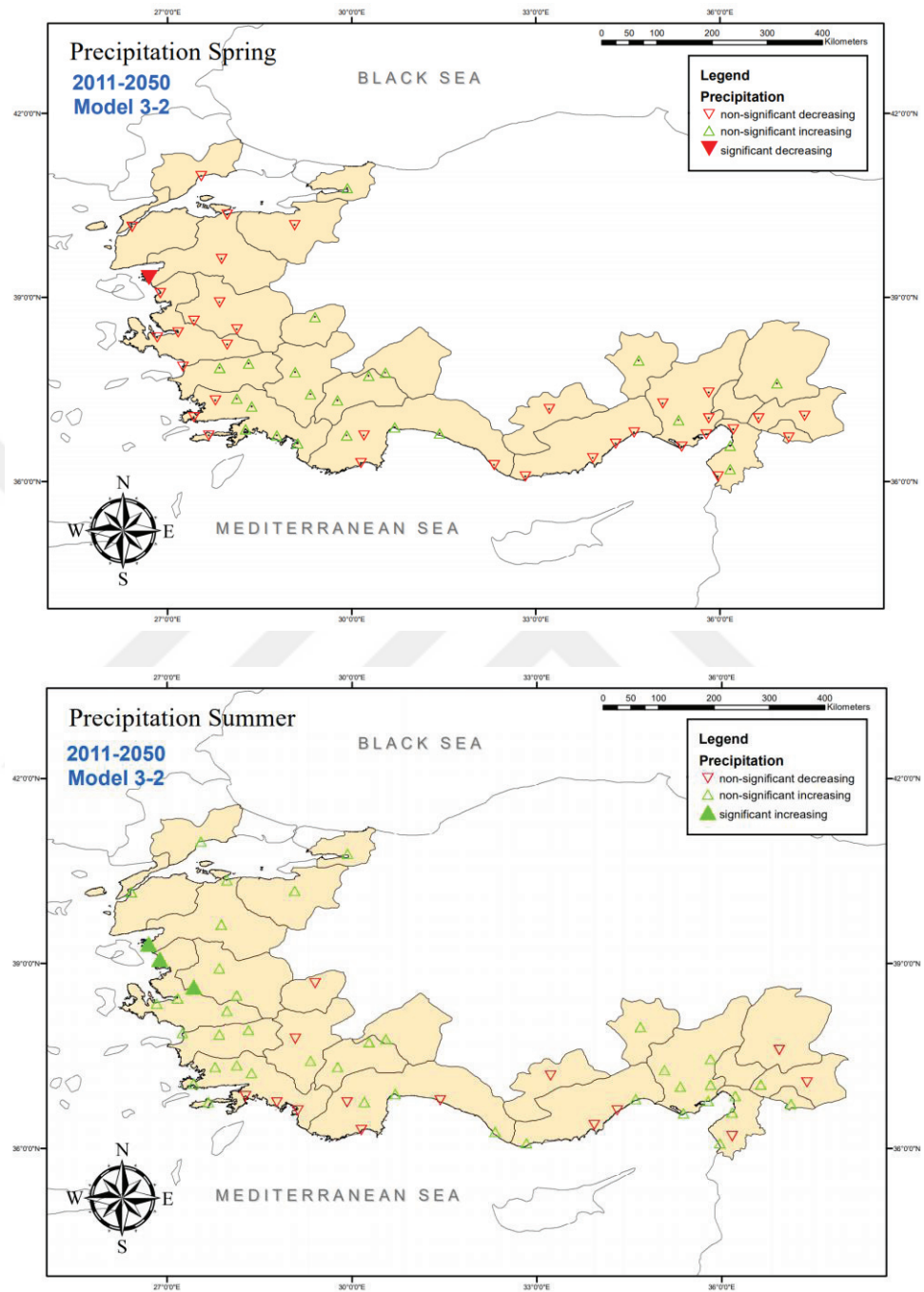


Figure 3.44. Spatial distribution of seasonal trends in precipitation of the region in the 2011-2050.

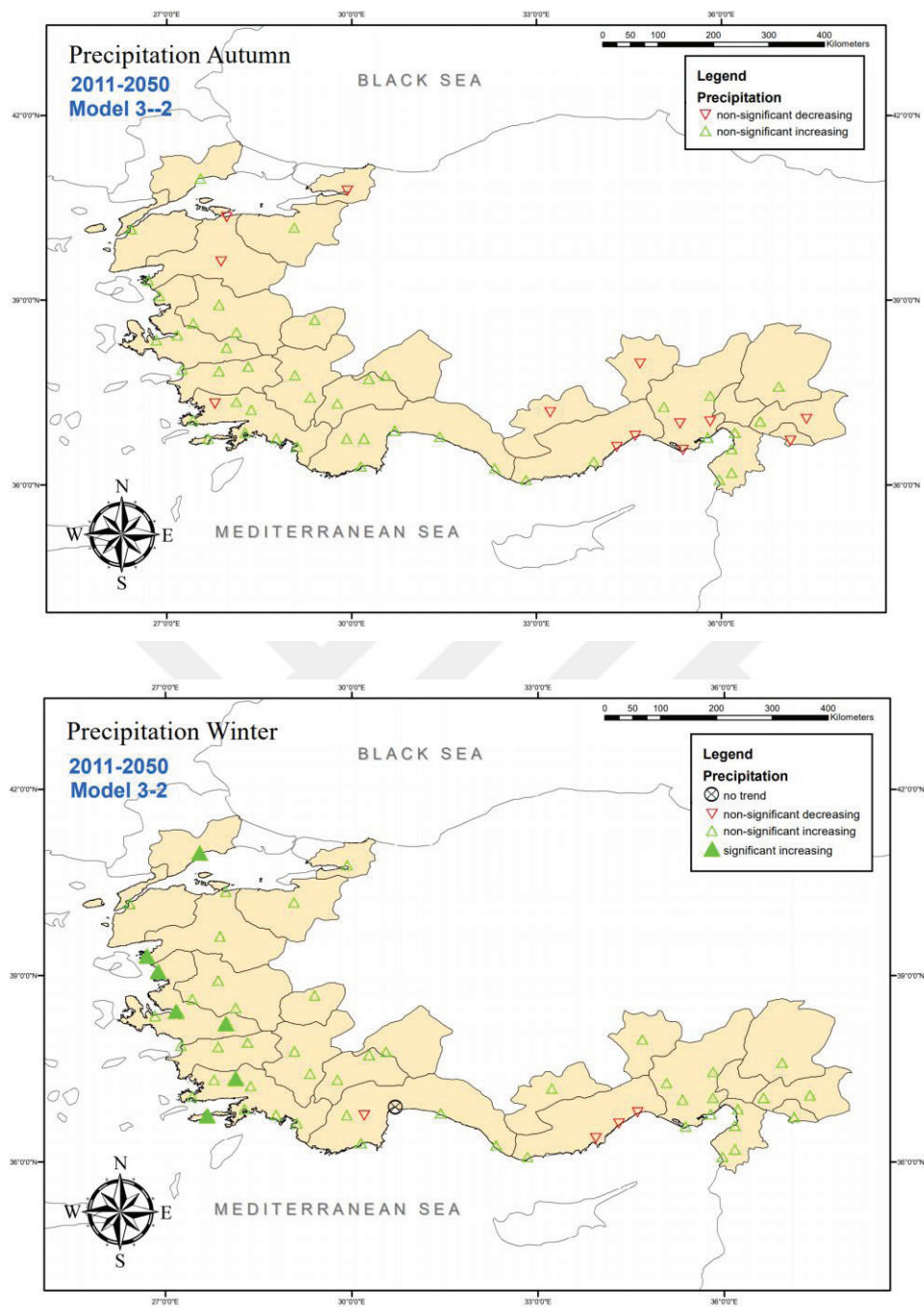


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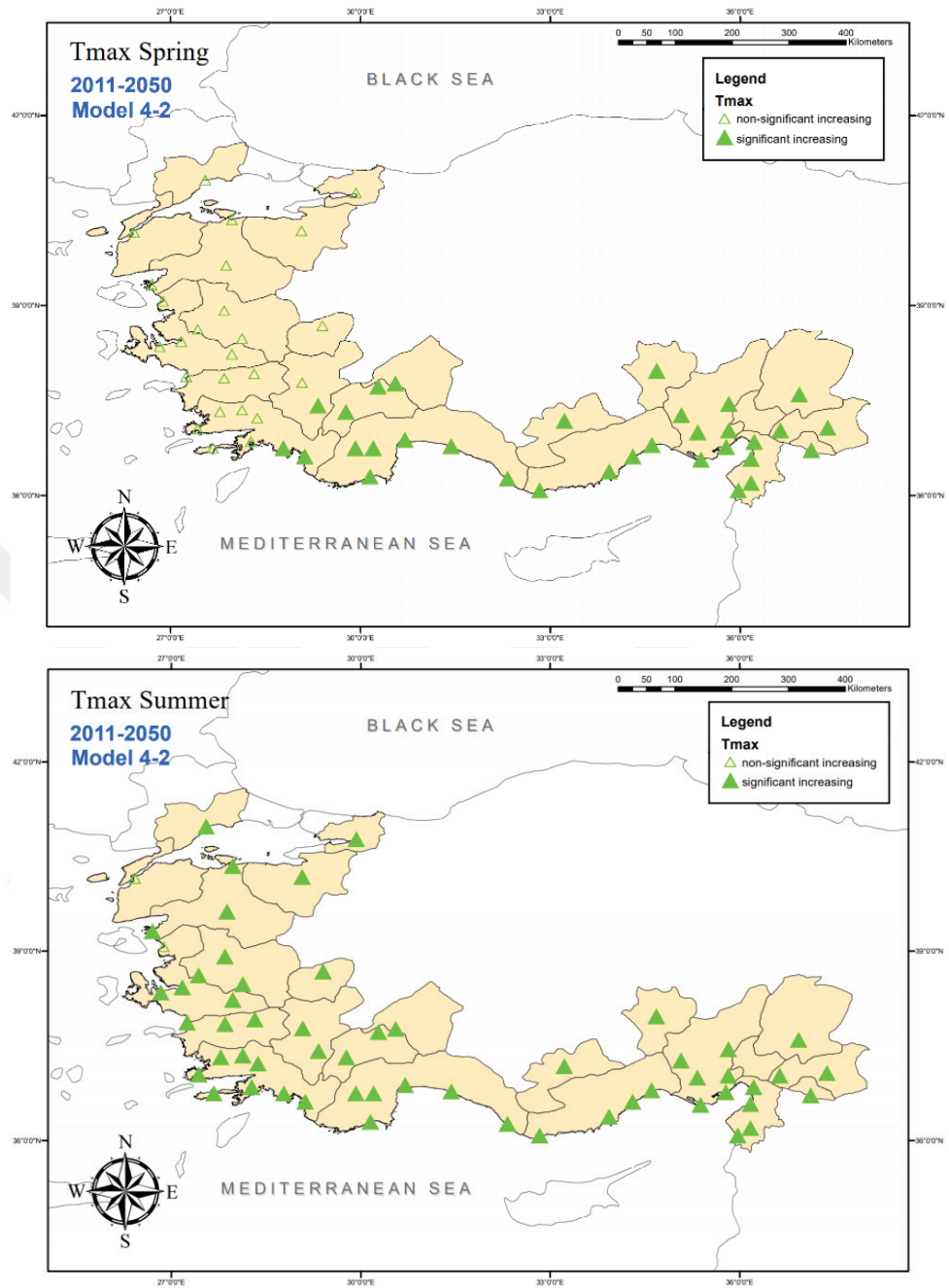


Figure 3.45. Spatial distributions of seasonal trends in maximum temperature of the region in the 2011-2050.

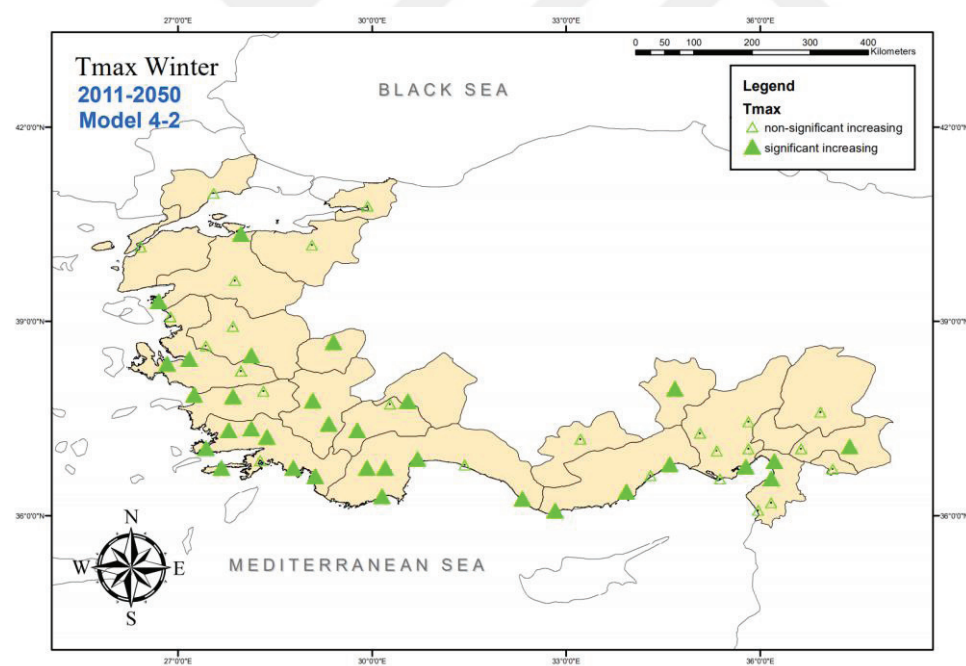
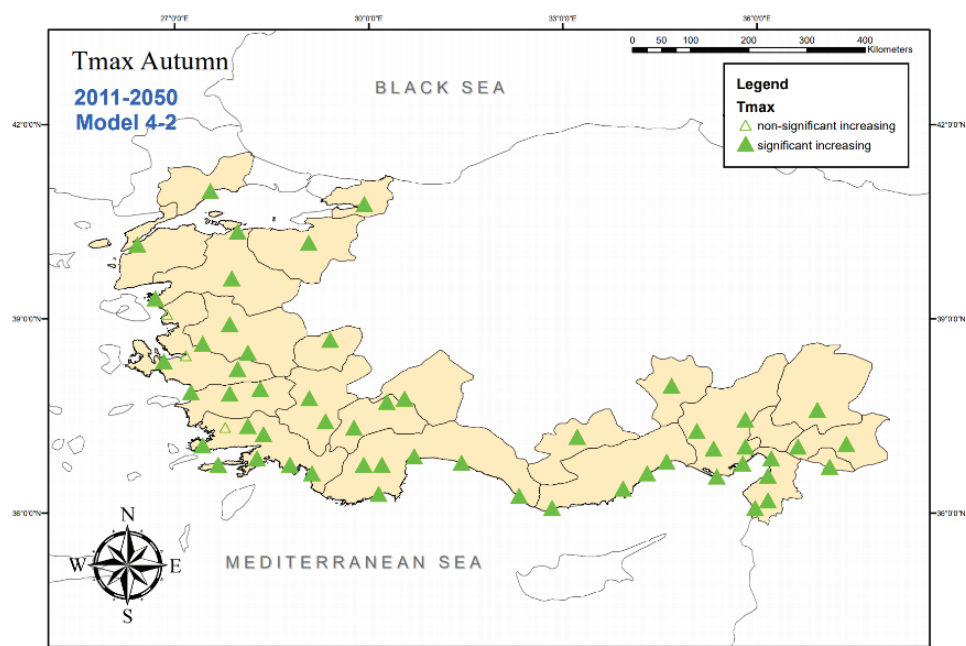


Figure 3.45. (cont'd)

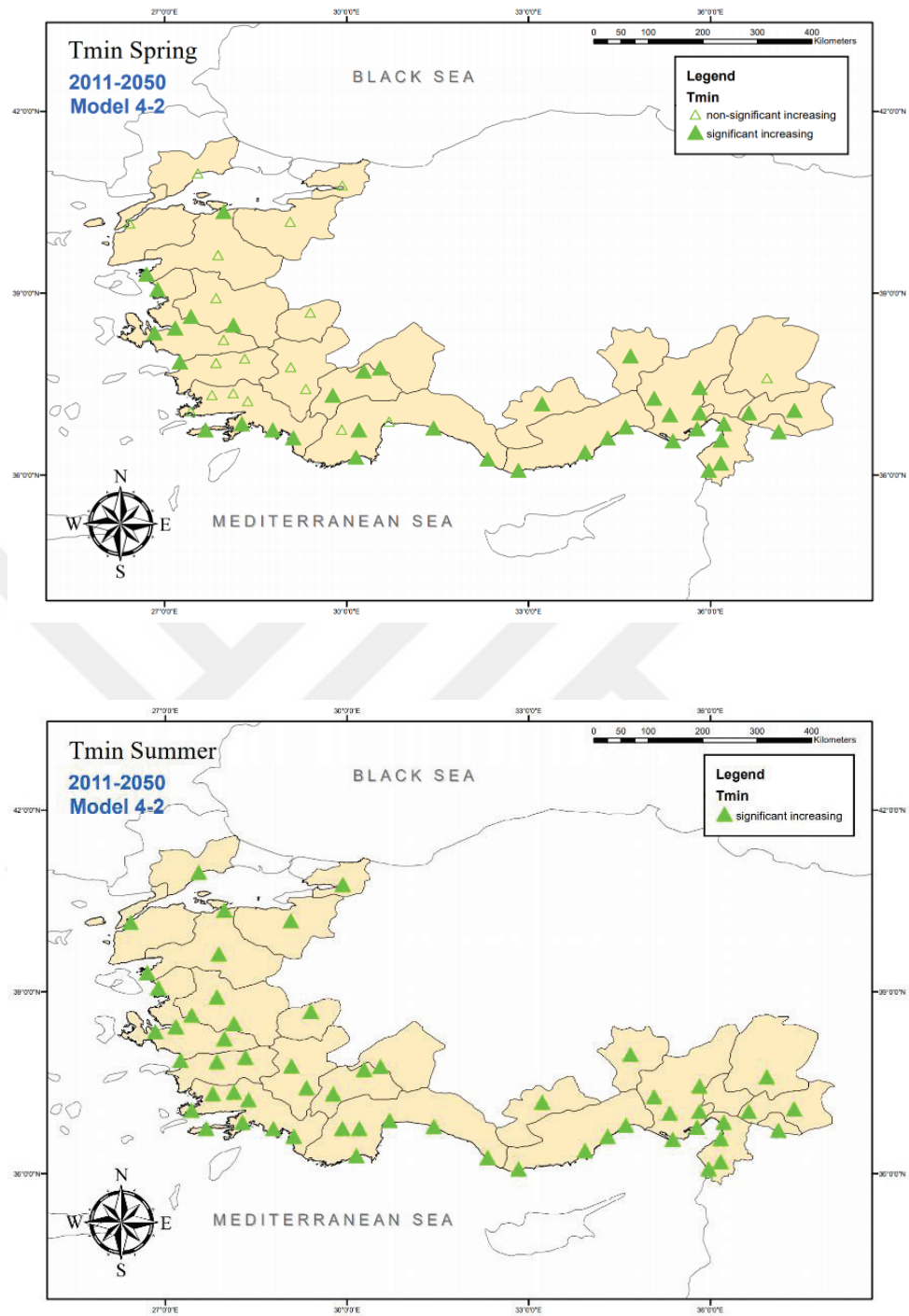


Figure 3.46. Spatial distributions of seasonal trends in minimum temperature of the region in the 2011-2050.

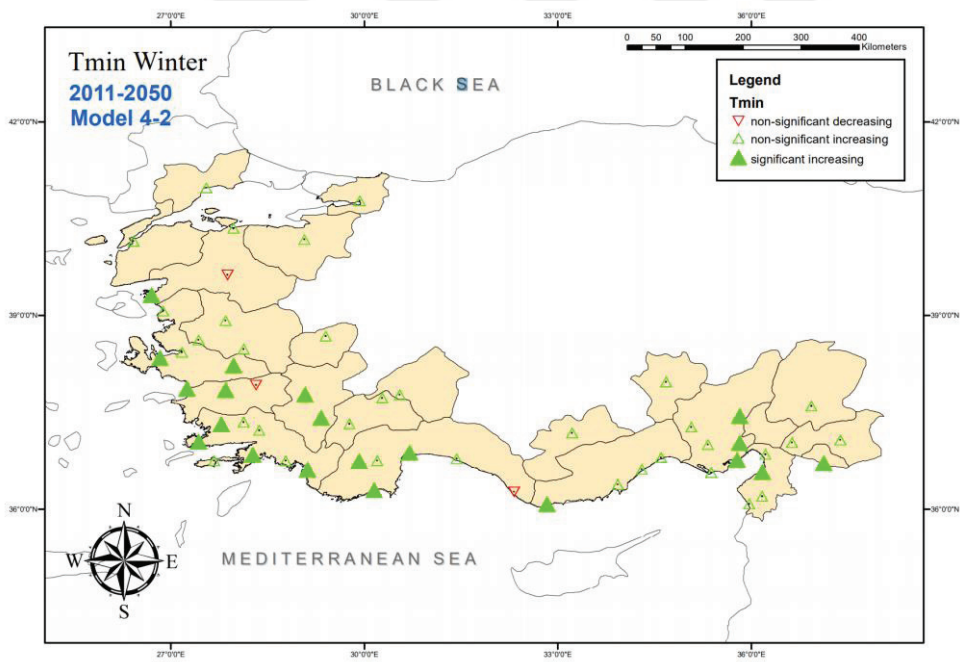
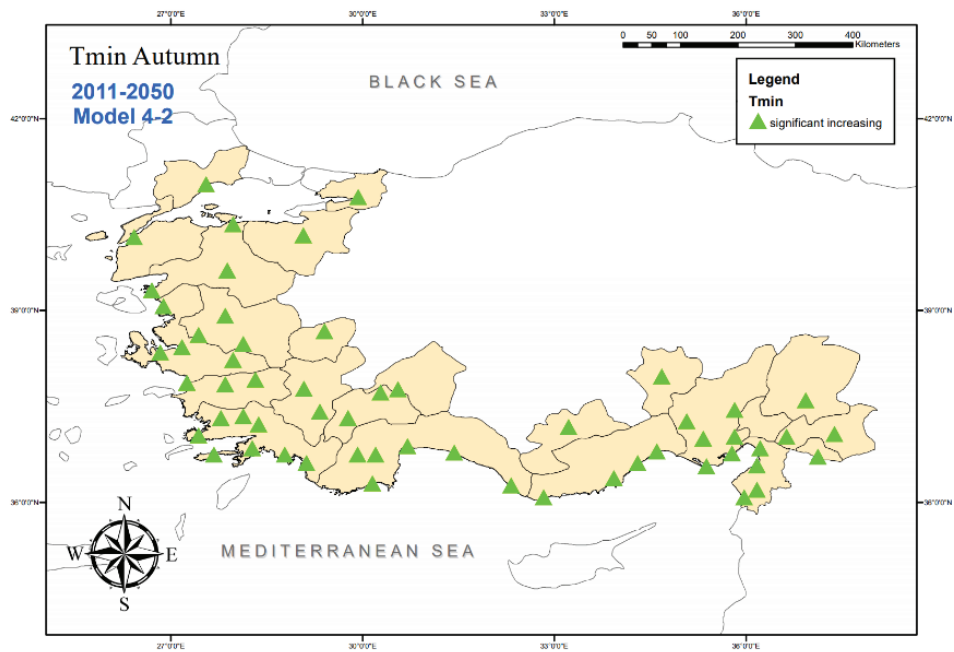


Figure 3.46. (cont'd)

E. Spring Trends of Climate Indices in 2011-2050

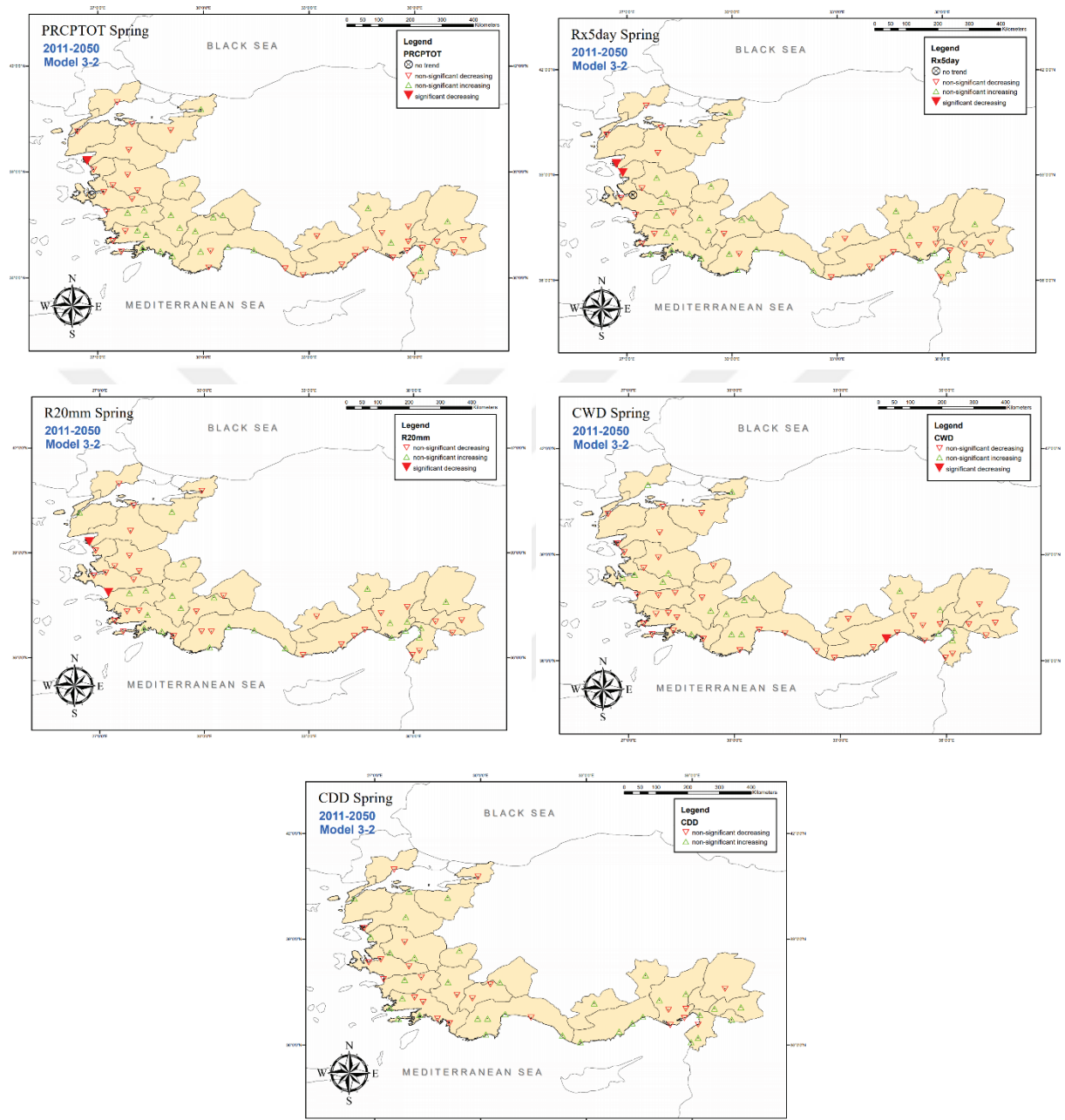


Figure 3.47. Spring trends of PRCPTOT, Rx5day, R20mm, CWD and CDD indicators in 2011-2050.

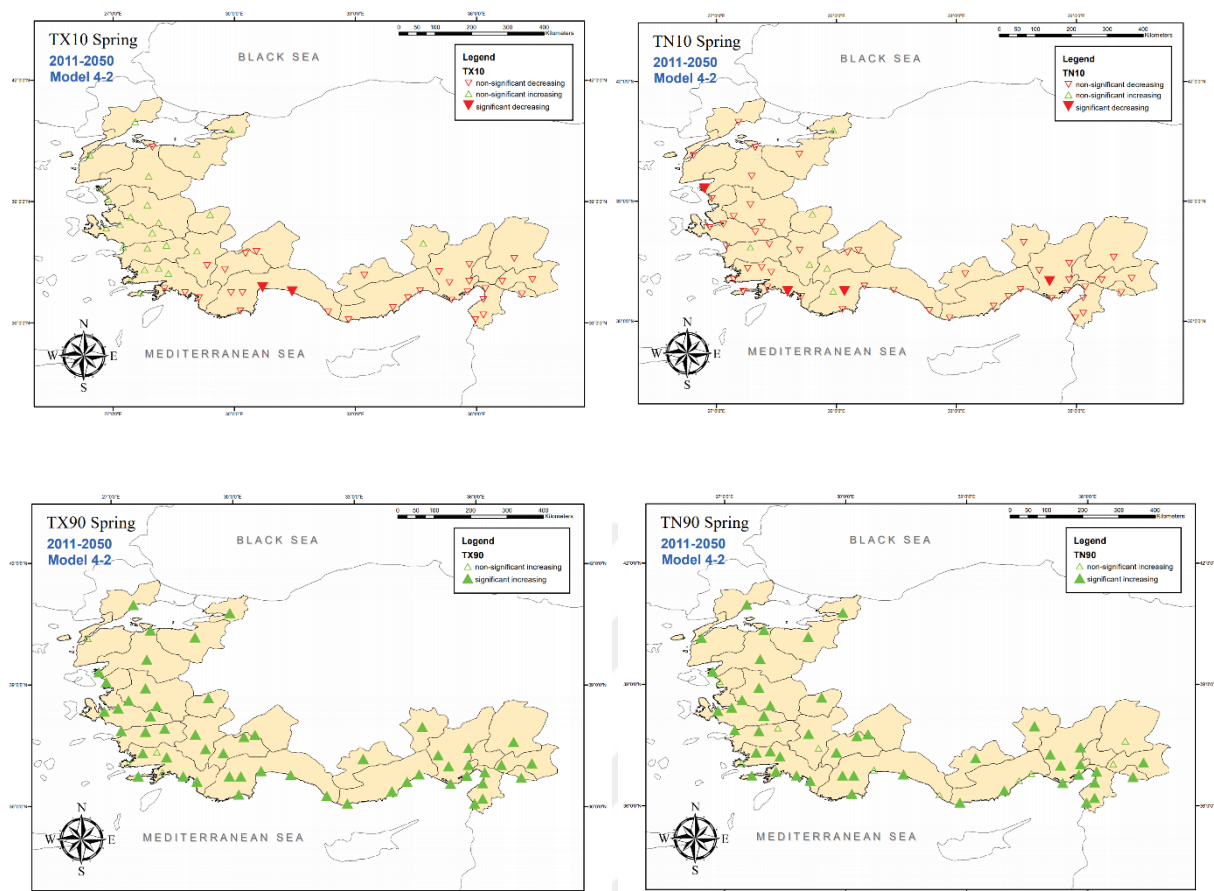


Figure 3.48. Spring trends of TX10, TN10, TX90 and TN90 indicators in 2011-2050.

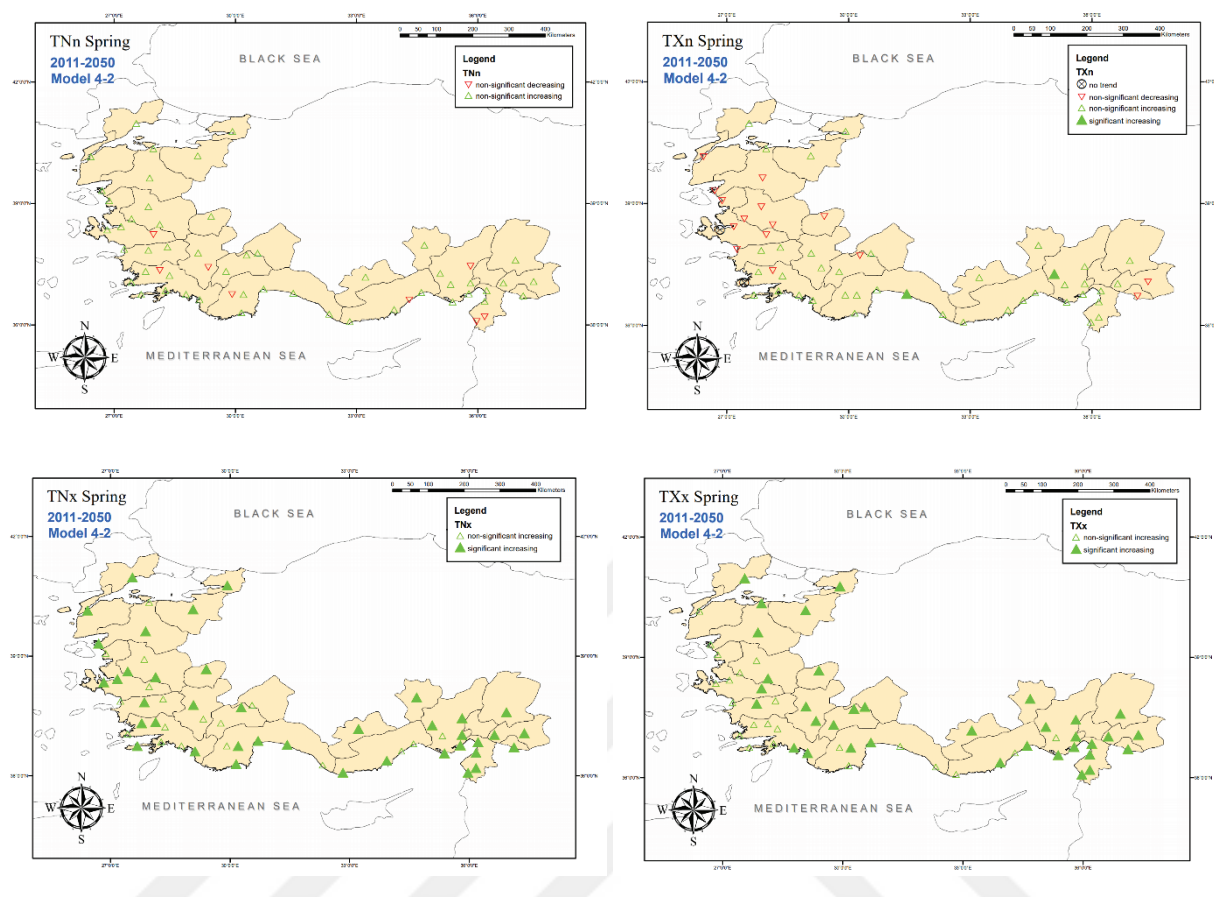


Figure 3.49. Spring trends of TNn, TXn, TNx and TXx indicators in 2011-2050.

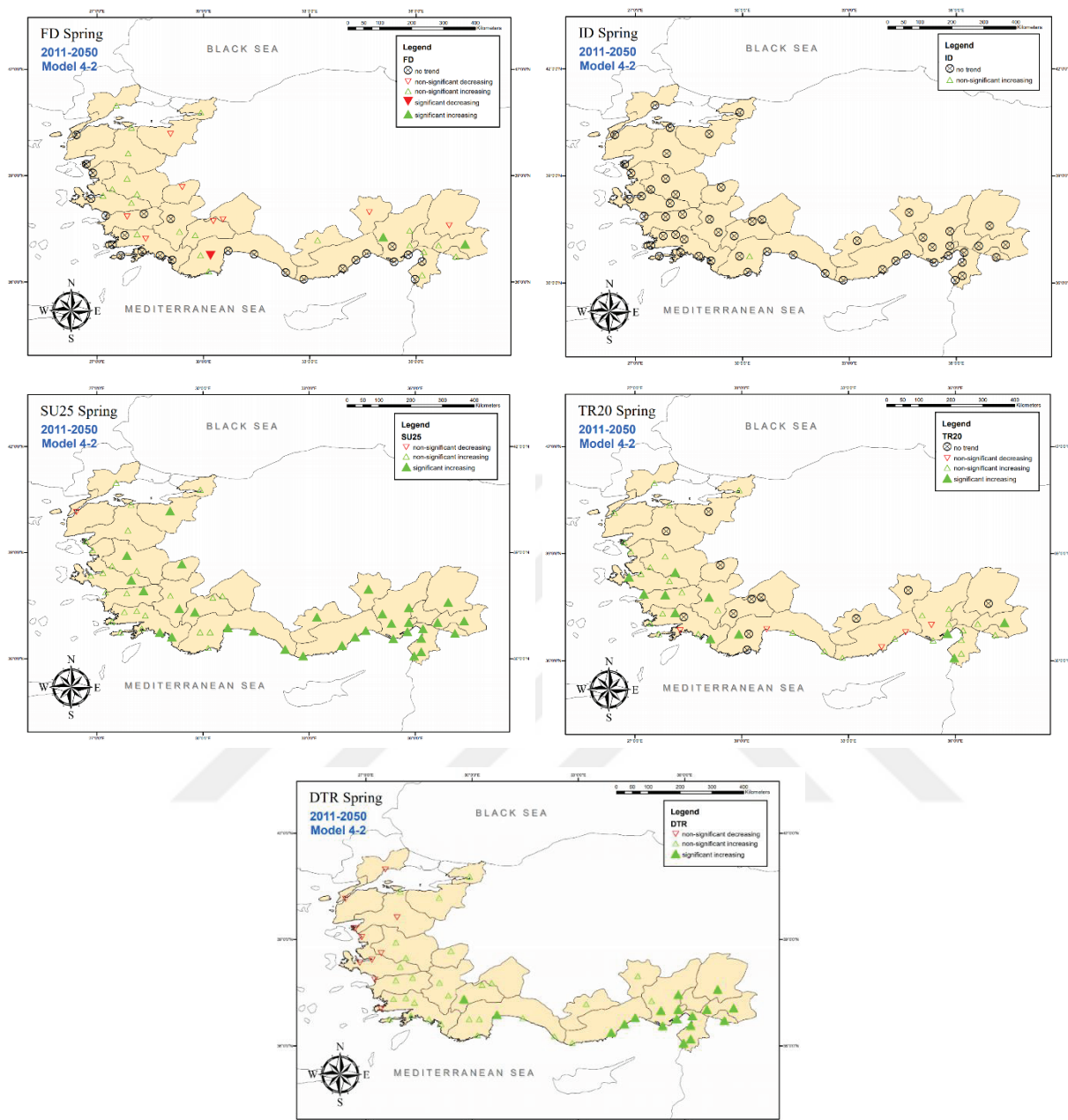


Figure 3.50. Spring trends of FD, ID, SU25, TR20 and DTR indicators in 2011-2050.

F. Summer Trends of Climate Indices in 2011-2050

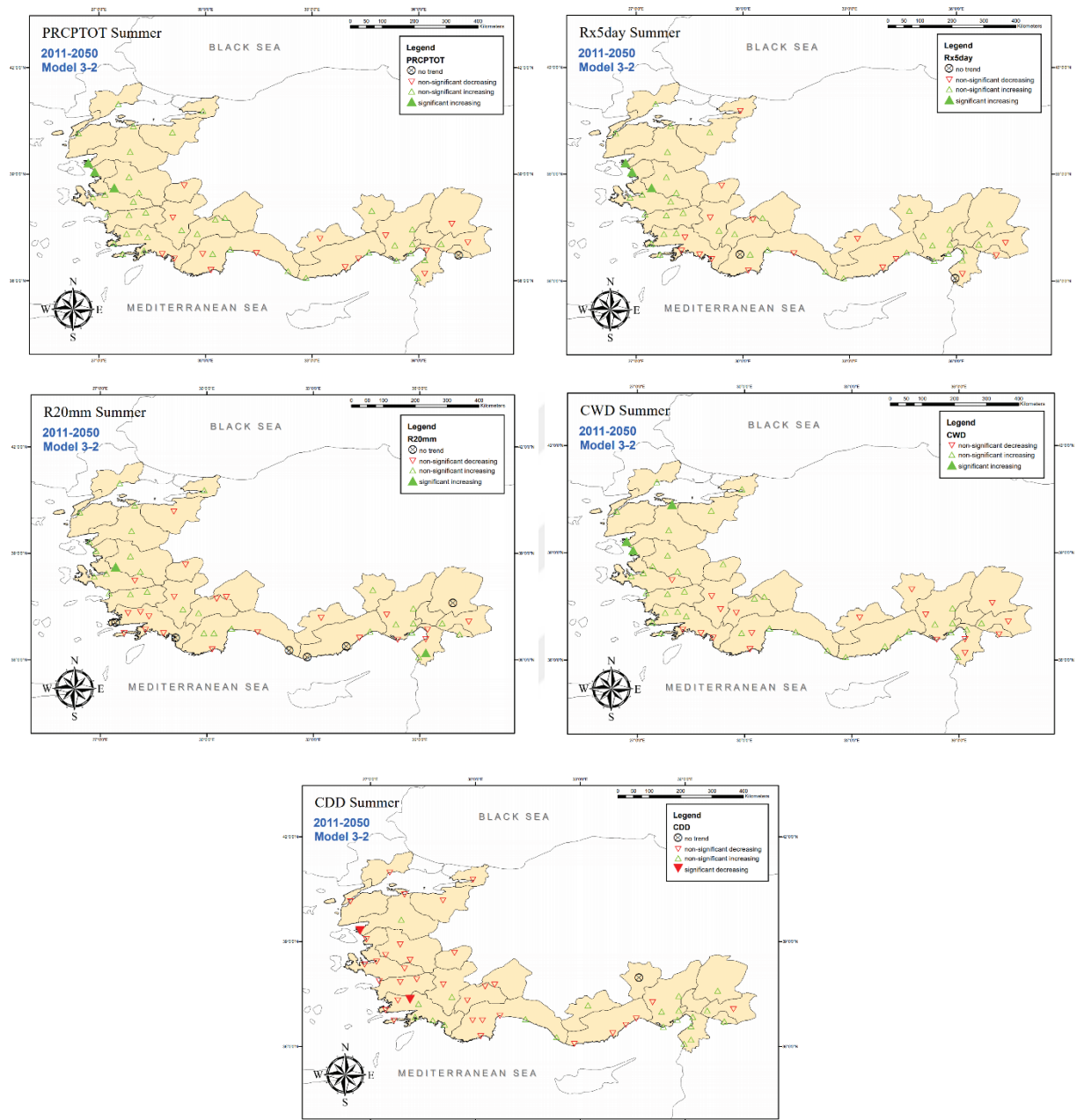


Figure 3.51. Summer trends of PRCPTOT, Rx5day, R20mm, CWD and CDD indicators in 2011-2050.

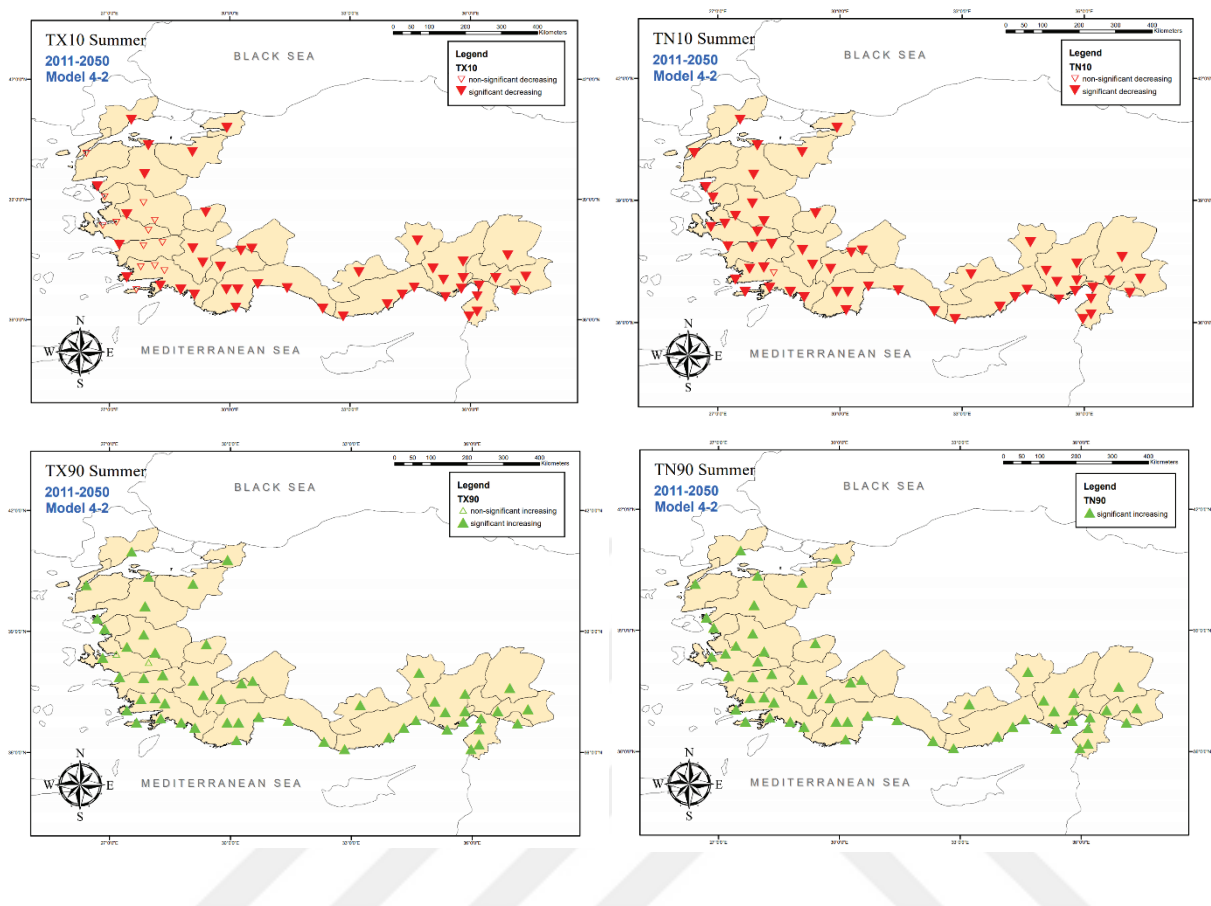


Figure 3.52. Summer trends of TX10, TN10, TX90 and TN90 indicators in 2011-2050.

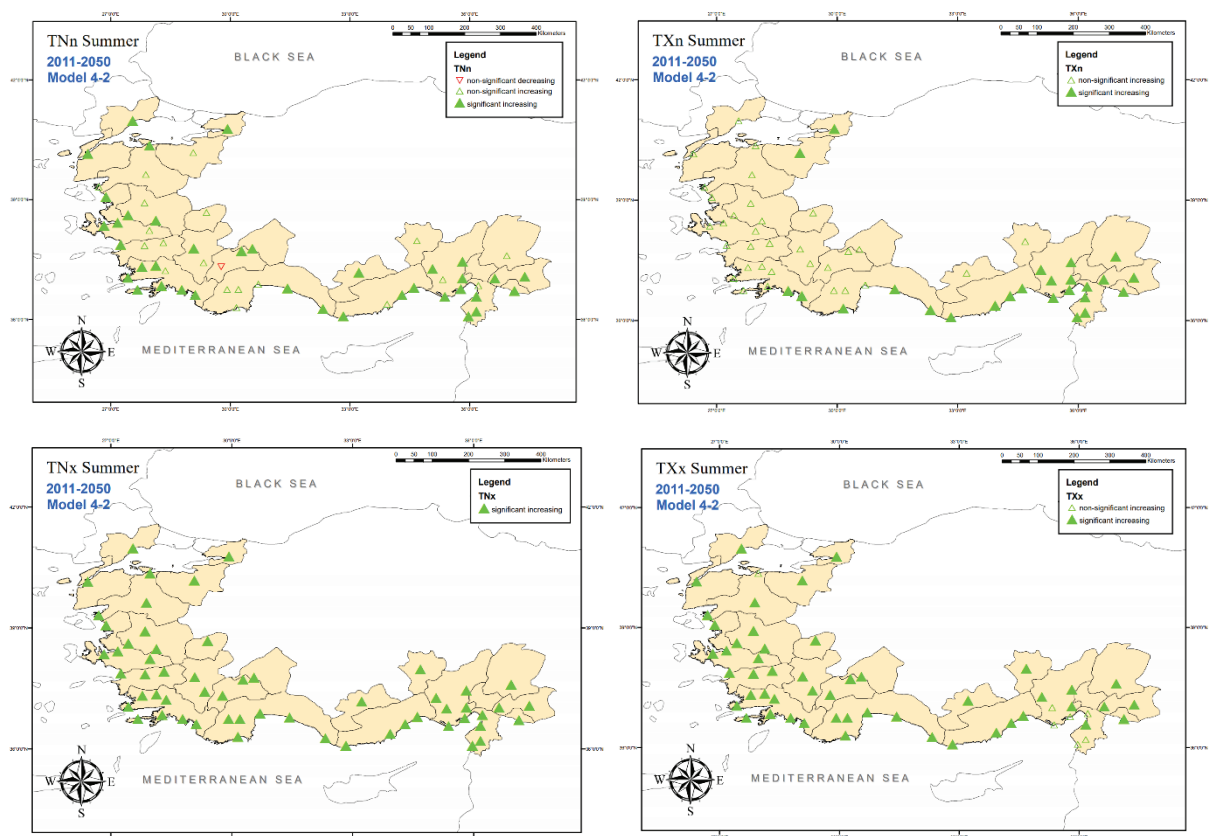


Figure 3.53. Summer trends of TNn, TXn, TNx and TXx indicators in 2011-2050.

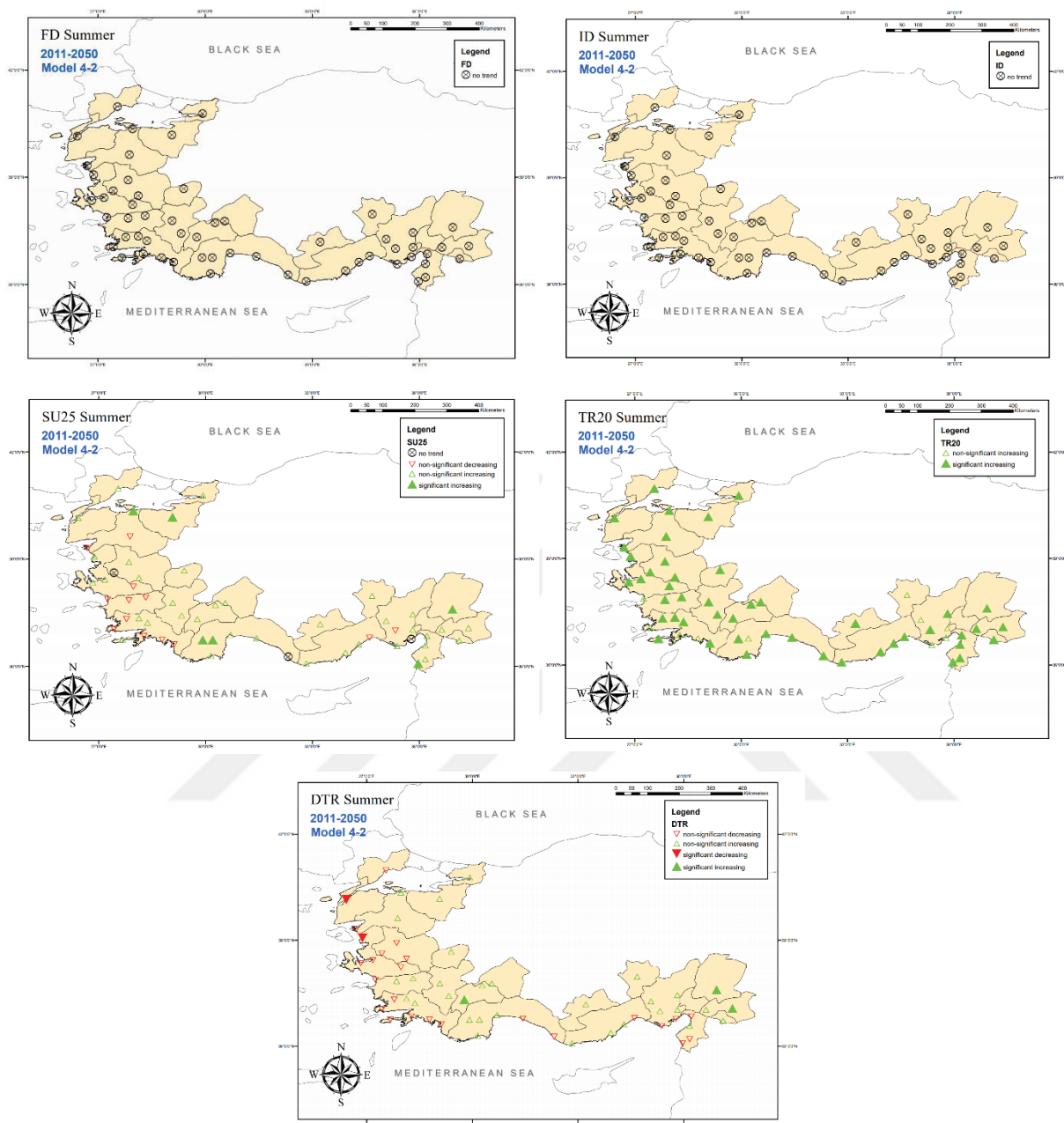


Figure 3.54. Summer trends of FD, ID, SU25, TR20 and DTR indicators in 2011-2050.

G. Autumn Trends of Climate Indices in 2011-2050

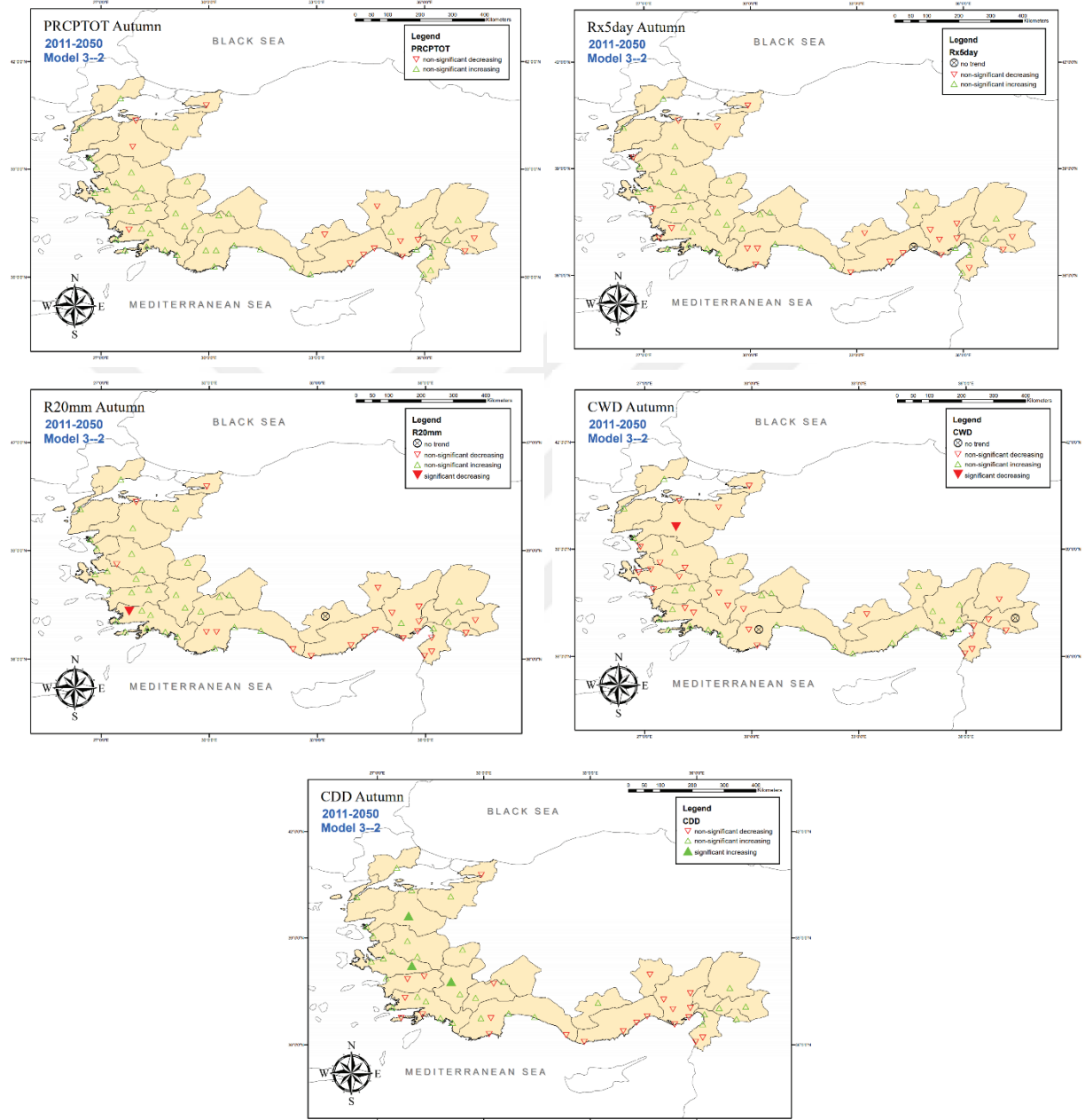


Figure 3.55. Autumn trends of PRCPTOT, Rx5day, R20mm, CWD and CDD indicators in 2011-2050.

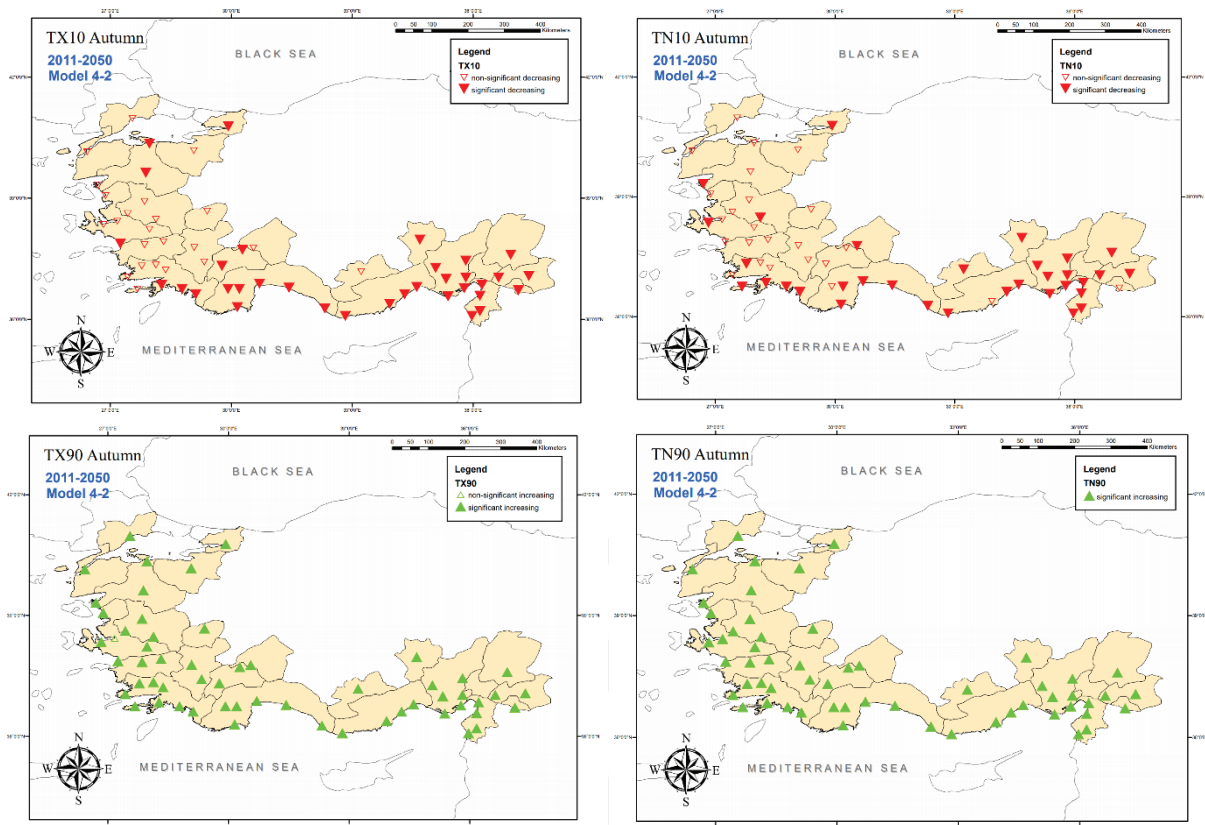


Figure 3.56. Autumn trends of TX10, TN10, TX90 and TN90 indicators in 2011-2050.

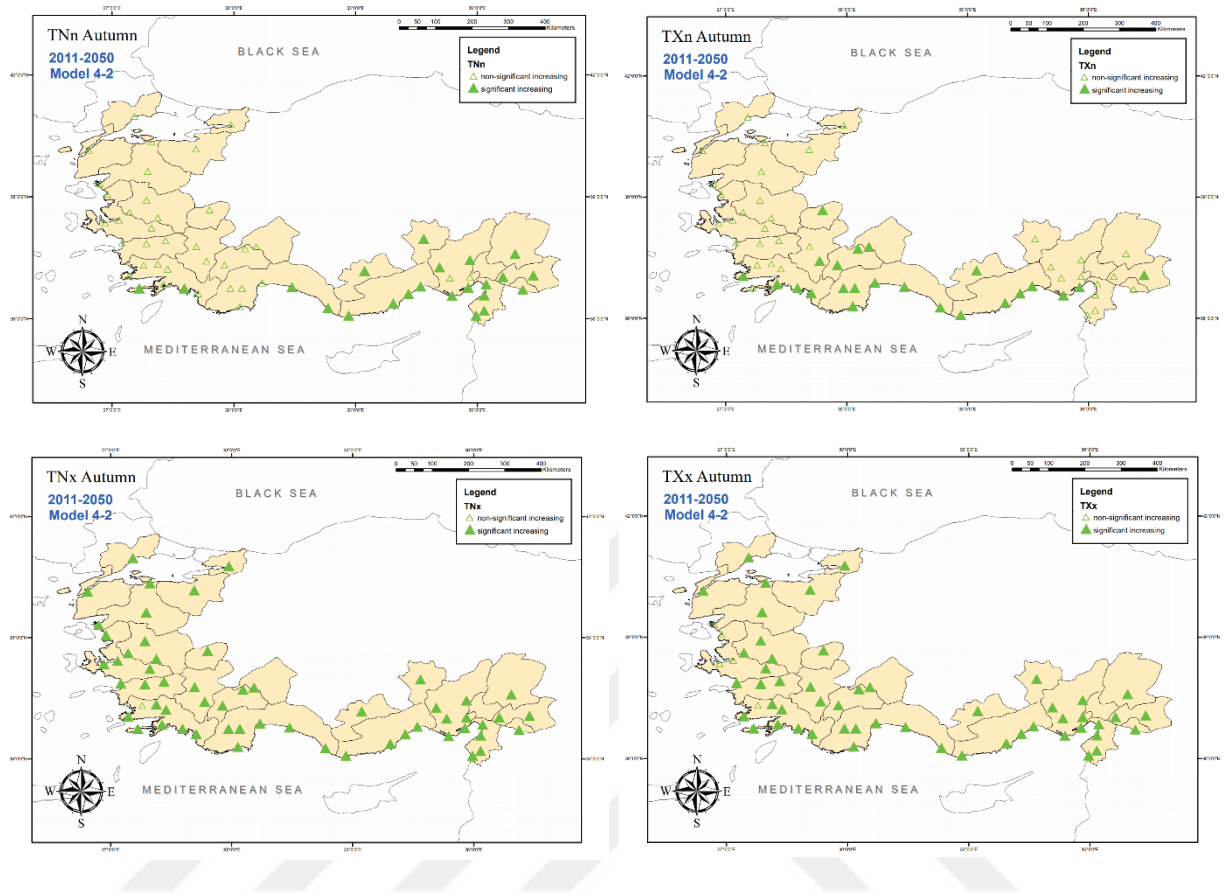


Figure 3.57. Autumn trends of TNn, TXn, TNx and TXx indicators in 2011-2050.

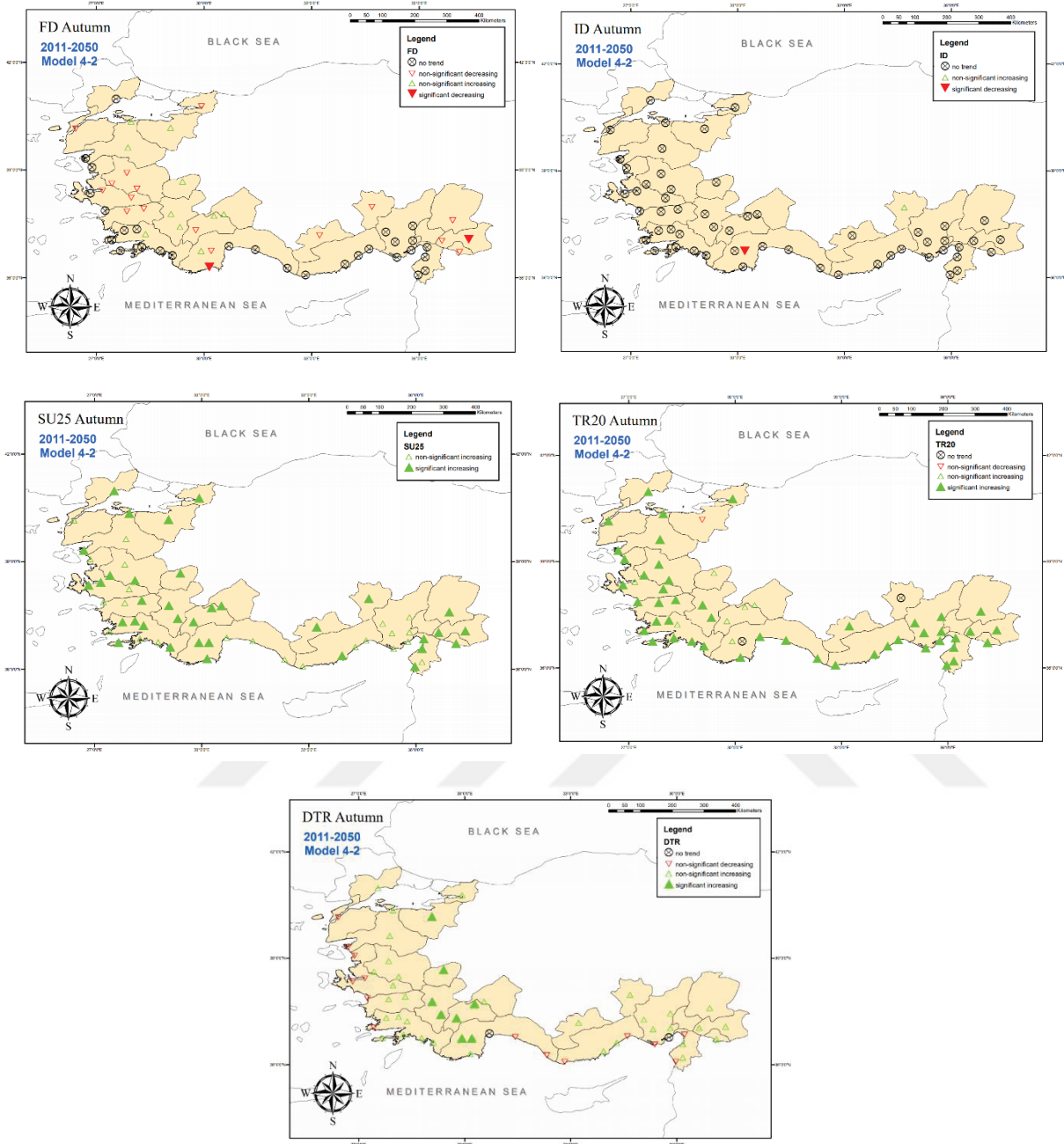


Figure 3.58. Autumn trends of FD, ID, SU25, TR20 and DTR indicators in 2011-2050.

H. Winter Trends of Climate Indices in 2011-2050

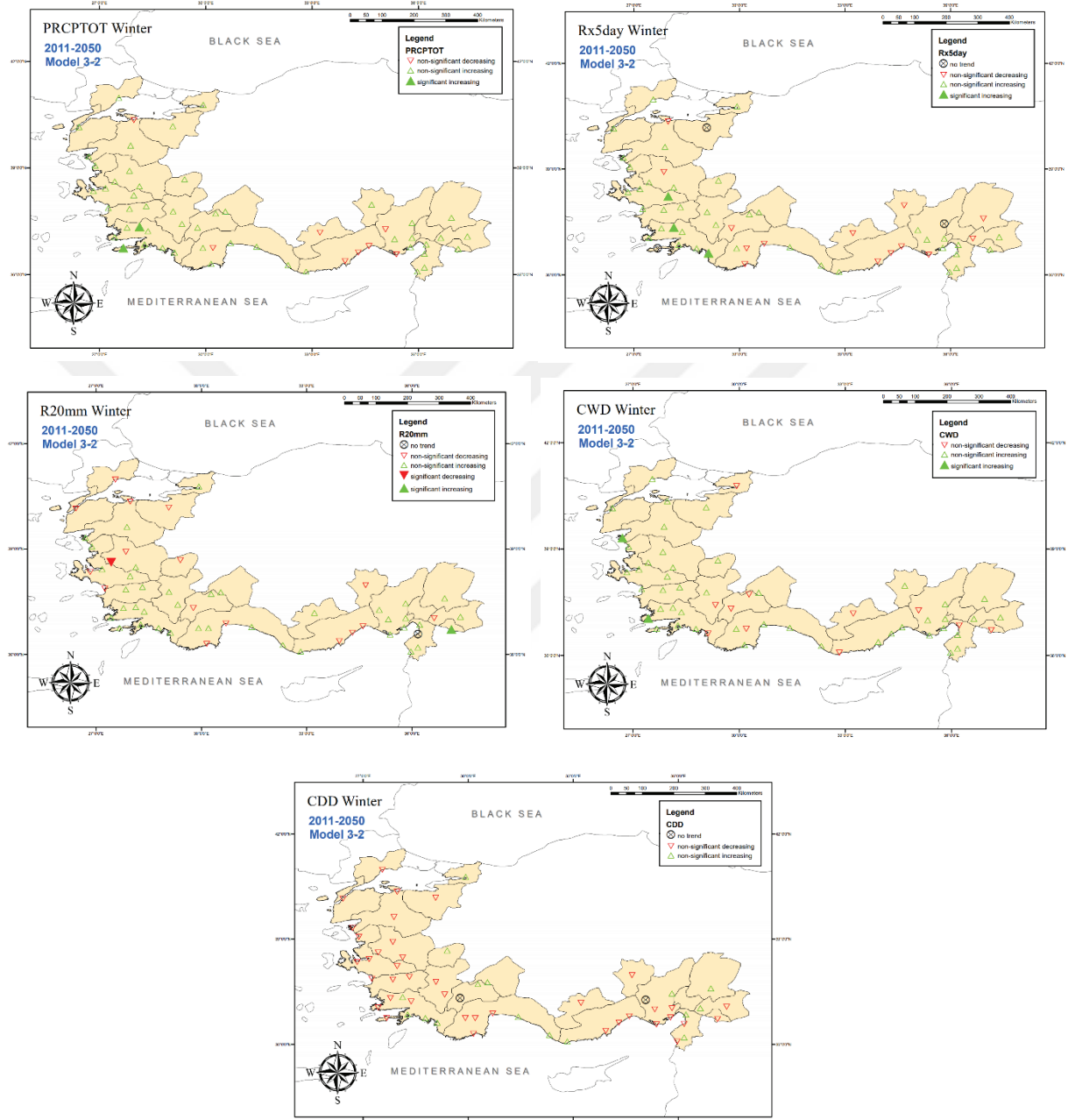


Figure 3.59. Winter trends of PRCPTOT, Rx5day, R20mm, CWD and CDD indicators in 2011-2050.

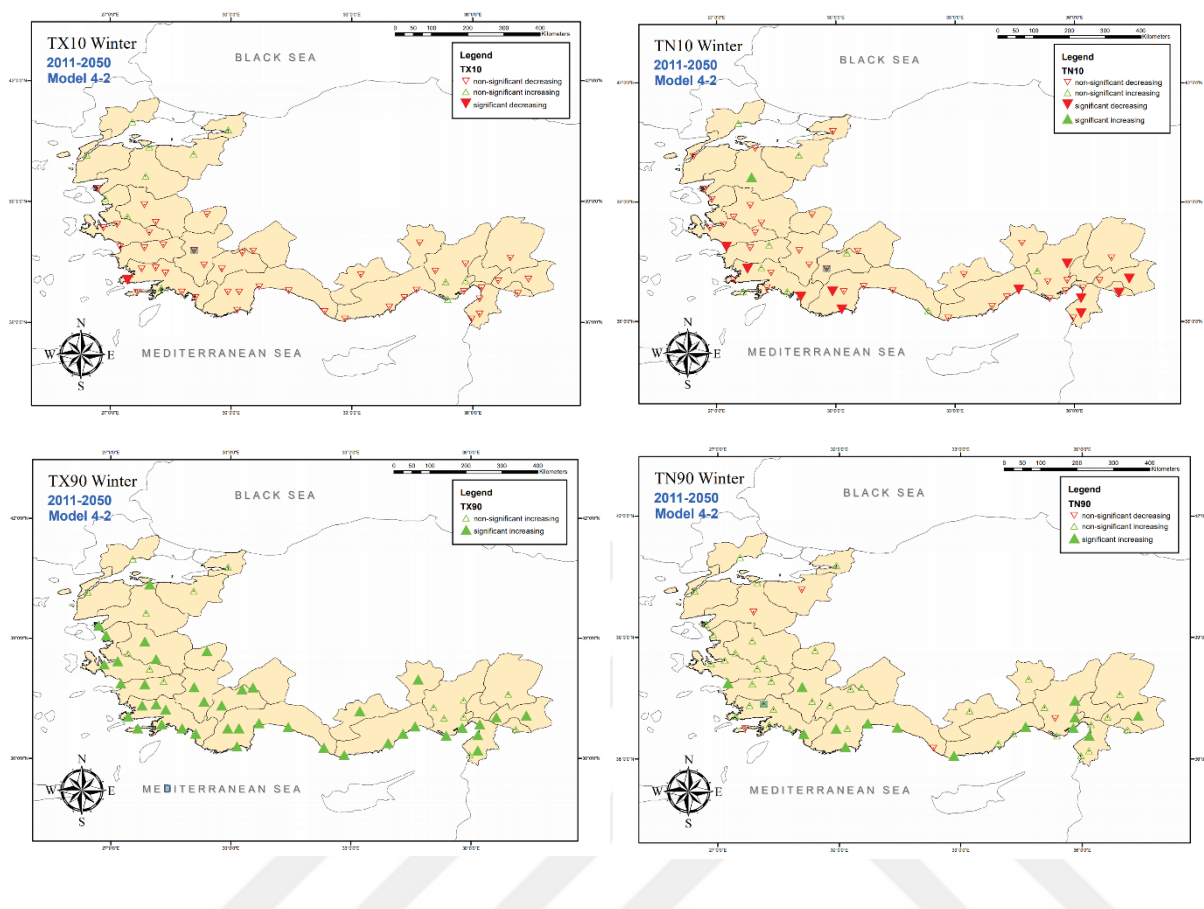


Figure 3.60. Winter trends of TX10, TN10, TX90 and TN90 indicators in 2011-2050.

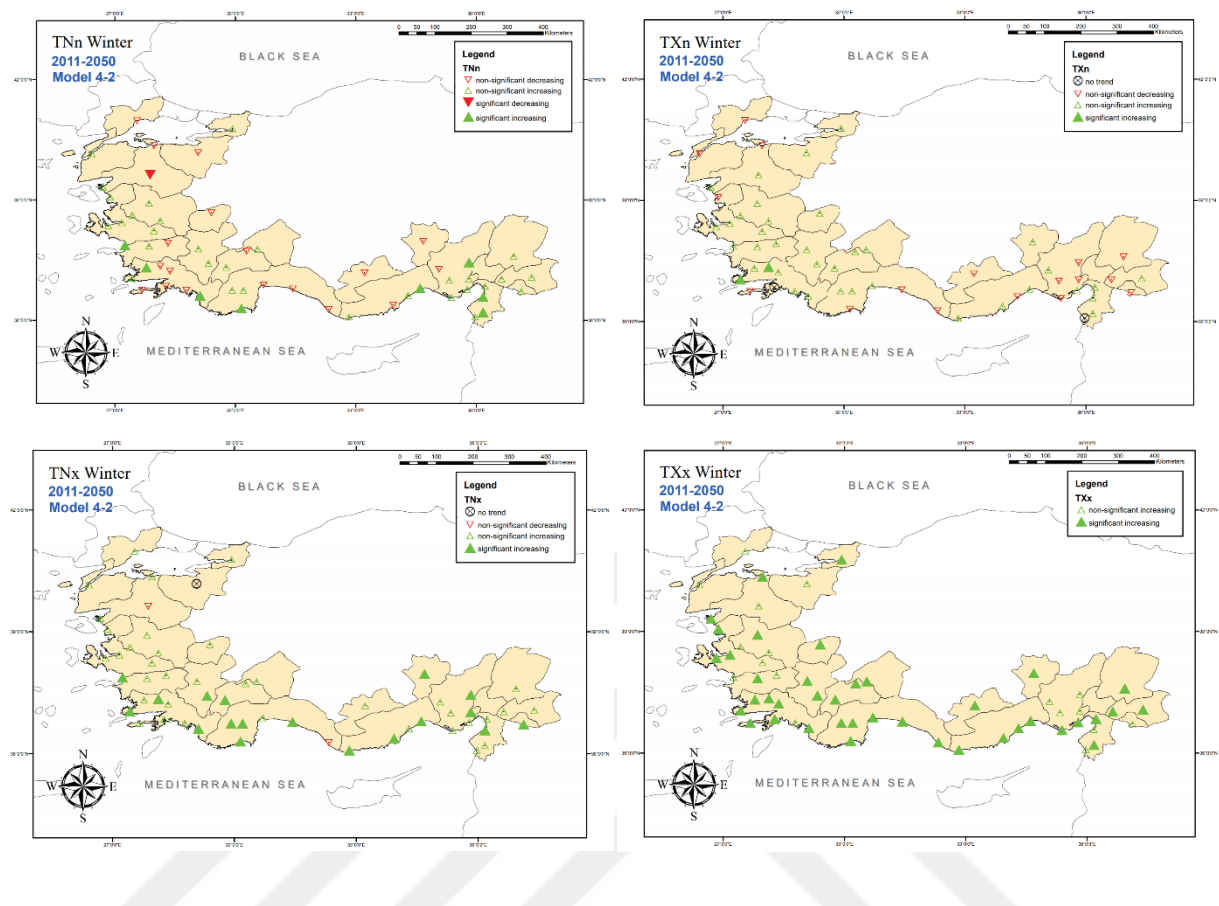


Figure 3.61. Winter trends of TNn, TXn, TNx and TXx indicators in 2011-2050.

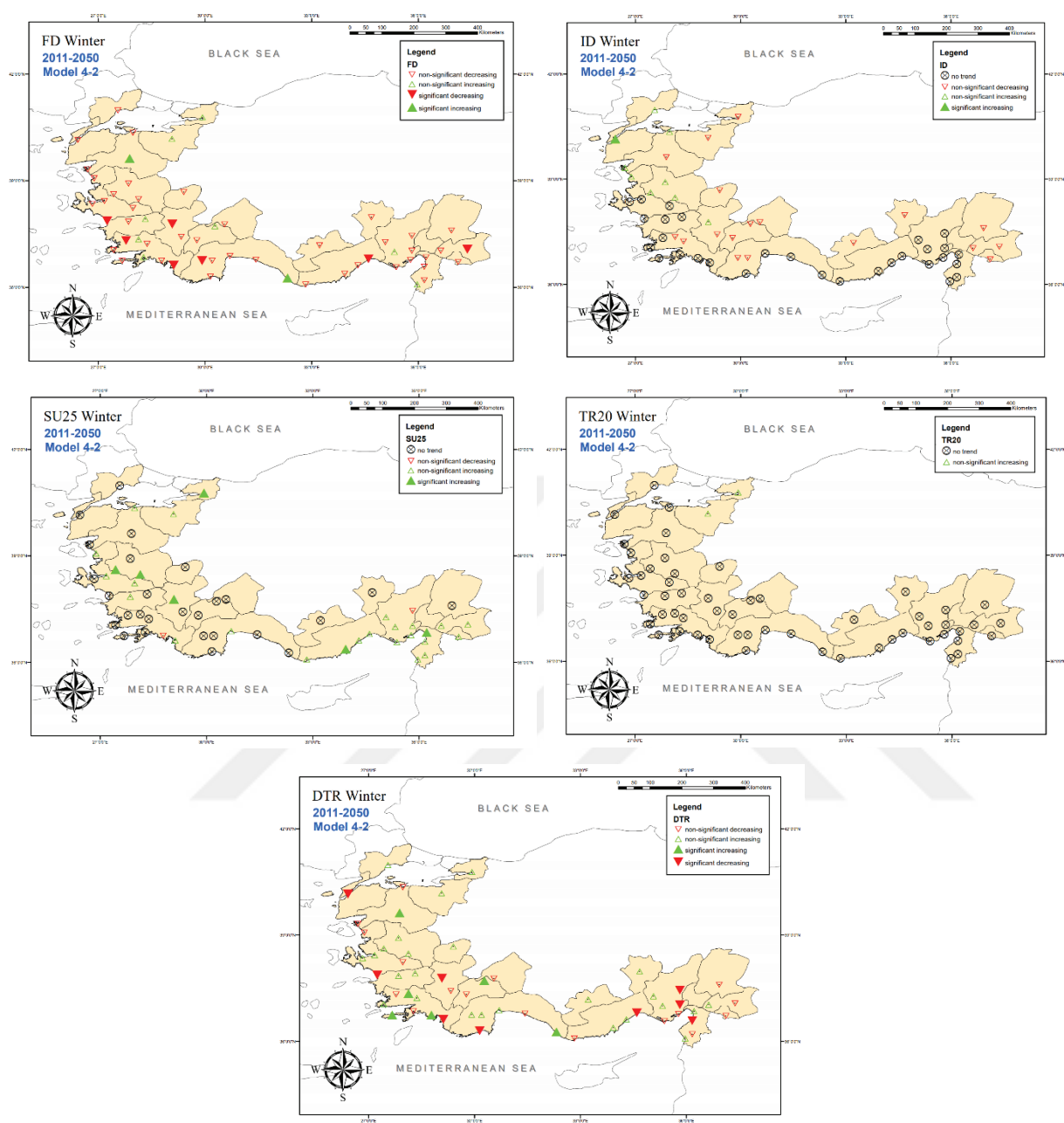


Figure 3.62. Winter trends of FD, ID, SU25, TR20 and DTR indicators in 2011-2050.

I. Annual and Seasonal Percentage Changes of Climate Indices

Table 3.19 Annual percentage change of climate indices.

Category	Index	Unit	Baseline	ANNUAL												% change	Model 4-2	% change
				Model 1-1	% change	Model 2-1	% change	Model 2-2	% change	Model 3-1	% change	Model 3-2	% change	Model 3-3	% change	Model 4-1		
Temperature indices	Percentile-based indices	TX10	%	10.41	9.99	6.61	28.07	27.51	10.04	9.78	10.09	10.19	1.46%	9.51	1.78%	9.69	10.64	2.23%
		TX90	%	9.85	9.92	16.18	15.07	15.76	2.03%	2.03%	2.03%	2.03%	2.03%	2.03%	2.03%	2.03%	2.03%	2.03%
		TN10	%	9.99	8.67	10.33	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09
		TN90	%	10.04	9.78	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09
	Absolute indices	TXx	°C	27.51	28.07	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02	28.02
		TNx	°C	4.49	6.61	4.49	6.61	4.49	6.61	4.49	6.61	4.49	6.61	4.49	6.61	4.49	6.61	4.49
		TNx	°C	16.18	16.85	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70
		TXn	°C	15.07	15.76	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29	15.29
	Threshold indices	FD	days	2.18	2.23	2.48%	2.19	2.19	2.48%	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
		ID	days	0.11	0.19	72.50%	0.15	0.15	72.50%	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Precipitation indices	Duration indices	SU25	days	11.39	12.56	10.28%	12.52	12.52	10.28%	12.52	12.52	12.52	12.52	12.52	12.52	12.52	12.52	12.52
		TR	days	3.75	5.17	38.07%	5.22	5.22	38.07%	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		GSL	days	346.58	343.10	-1.00%	346.77	346.77	-1.00%	346.77	346.77	346.77	346.77	346.77	346.77	346.77	346.77	346.77
		WSDI	days	4.42	5.88	33.03%	8.20	8.20	33.03%	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20
	Other index	CSDI	days	3.28	4.83	46.91%	5.83	5.83	46.91%	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83
		DTR	°C	10.74	10.41	-3.05%	10.53	10.53	-3.05%	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53
		R20mm	days	0.87	0.83	-4.97%	0.86	0.86	-4.97%	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Rx5day	mm	39.42	38.19	-3.12%	39.52	39.52	-3.12%	39.52	39.52	39.52	39.52	39.52	39.52	39.52	39.52	39.52
	Intensity indices	PRCPTOT	mm	61.23	65.10	6.33%	67.87	67.87	6.33%	67.87	67.87	67.87	67.87	67.87	67.87	67.87	67.87	67.87
		R95p	mm	156.97	174.20	10.97%	177.14	177.14	10.97%	177.14	177.14	177.14	177.14	177.14	177.14	177.14	177.14	177.14
	Other indices	CDD	days	22.35	18.65	-16.56%	17.98	17.98	-16.56%	17.98	17.98	17.98	17.98	17.98	17.98	17.98	17.98	17.98
		CWD	days	2.48	3.37	35.77%	3.34	3.34	35.77%	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
		R95pTOT	%	21.57	21.83	1.21%	21.36	21.36	1.21%	21.36	21.36	21.36	21.36	21.36	21.36	21.36	21.36	21.36

Table 3.20 Spring percentage change of climate indices.

Category		Index	Unit	Baseline	Model 1-1	% change	Model 2-1	% change	Model 2-2	% change	SPRING								
Percentile-based indices	TX10	%	10.37	8.74	-15.72%	10.41	0.36%	10.27	-0.93%	8.47	-18.29%	10.06	-2.94%	8.58	-17.26%	8.71	-16.02%	10.19	-1.75%
	TX90	%	9.71	9.87	1.63%	10.28	5.83%	10.41	7.16%	9.67	-0.47%	10.31	6.20%	9.74	0.31%	9.87	1.67%	10.42	7.29%
	TN10	%	10.31	8.67	-15.91%	10.37	0.61%	10.21	-1.02%	8.42	-18.29%	10.04	-2.66%	8.36	-18.93%	10.11	-1.92%	10.02	-2.85%
	TN90	%	9.71	9.64	-0.73%	10.22	5.27%	10.26	5.75%	9.54	-1.75%	10.11	4.17%	9.49	-2.21%	10.18	4.86%	10.27	5.79%
	TXx	°C	27.70	27.71	0.03%	27.62	-0.31%	27.76	0.20%	28.53	2.99%	28.91	4.35%	28.50	2.87%	28.80	3.98%	28.80	3.97%
Temperature indices	TNn	°C	4.06	5.65	38.99%	3.89	-4.16%	4.50	10.71%	5.32	31.05%	6.46	59.15%	5.61	38.11%	5.32	30.92%	5.39	32.81%
	TNx	°C	15.28	15.58	1.96%	15.01	-1.79%	16.02	4.80%	15.77	3.16%	15.98	4.58%	16.10	5.33%	16.27	6.47%	16.12	5.45%
	TXn	°C	13.51	14.14	4.62%	12.54	-7.23%	12.93	-4.30%	14.41	6.63%	15.39	13.91%	14.95	10.66%	14.69	8.67%	14.44	6.89%
	FD	days	1.18	0.94	-20.64%	1.77	50.20%	1.16	-1.75%	0.98	-16.54%	0.44	-63.02%	0.87	-26.11%	0.58	-50.72%	0.64	-45.94%
	ID	days	0.02	0.02	-23.15%	0.06	179.88%	0.07	242.97%	0.00	-78.21%	0.00	-85.09%	0.00	-87.38%	0.00	-96.56%	0.00	-94.26%
Other index	SU25	days	6.85	7.52	9.76%	7.27	6.11%	7.80	13.78%	7.77	13.33%	9.30	35.69%	8.61	25.61%	8.65	26.25%	8.29	20.95%
	TR	days	0.28	0.67	138.83%	0.70	149.95%	0.66	134.12%	0.61	118.46%	1.07	279.64%	0.75	167.03%	0.70	147.28%	0.51	82.44%
	DTR	°C	10.97	10.59	-3.43%	10.77	1.75%	10.57	-3.65%	11.02	0.52%	10.93	-0.35%	10.97	0.08%	11.02	0.48%	10.90	-0.56%
	R20mm	days	0.64	0.64	-0.51%	0.67	4.37%	0.89	38.43%	0.67	4.60%	0.63	-2.30%	0.69	8.15%	0.61	-4.80%	0.54	-15.14%
	Rx5day	mm	35.53	37.26	4.86%	37.34	5.09%	44.58	25.46%	38.36	7.96%	35.82	0.81%	37.03	4.21%	34.74	-2.22%	32.52	-8.48%
Precipitation indices	PRCPTOT	mm	54.40	64.67	18.87%	62.94	15.70%	75.74	39.24%	62.06	14.08%	60.92	11.99%	57.84	6.32%	55.34	1.73%	55.16	1.40%
	CDD	days	14.13	11.62	-17.76%	12.95	-8.36%	11.89	-15.82%	13.54	-4.14%	13.82	-2.22%	14.83	4.95%	14.15	0.18%	12.67	-10.29%
	CWD	days	2.71	3.77	39.06%	3.59	32.39%	3.77	38.97%	3.59	32.36%	3.57	31.47%	3.34	23.01%	3.02	11.41%	2.96	9.19%

Table 3.21 Summer percentage change of climate indices.

Category	Index	Unit	Baseline	SUMMER										Model 4-2	% change					
				Model 1-1	% change	Model 2-1	% change	Model 2-2	% change	Model 3-1	% change	Model 3-2	% change			Model 3-3	% change	Model 4-1	% change	
Temperature indices	Percentile-based indices	TX10	%	9.81	11.50	17.16%	10.73	9.34%	10.28	4.78%	11.26	14.77%	10.04	2.28%	11.38	15.97%	11.65	18.70%	10.69	8.94%
		TX90	%	9.93	9.97	0.39%	9.62	-3.18%	10.12	1.90%	9.50	-4.29%	10.39	4.60%	9.54	-3.89%	9.79	-1.40%	8.59	-13.46%
		TN10	%	9.01	7.62	-15.36%	10.42	15.70%	10.15	12.73%	7.50	-16.79%	9.94	10.32%	7.60	-15.62%	10.03	11.40%	10.21	13.39%
		TN90	%	10.26	9.82	-4.25%	9.75	-4.97%	10.21	-0.51%	9.23	-10.05%	10.16	-0.96%	9.17	-10.60%	10.30	0.40%	9.31	-9.27%
	Absolute indices	TXx	°C	36.71	36.73	0.05%	36.70	-0.05%	36.98	0.73%	37.68	2.64%	37.86	3.14%	37.88	3.17%	36.72	0.01%	36.50	-0.59%
		TNn	°C	15.49	16.56	6.86%	16.00	3.28%	16.37	5.66%	17.24	11.28%	17.82	15.02%	17.64	13.88%	16.94	9.36%	15.78	1.86%
		TNx	°C	23.38	23.80	1.79%	23.62	1.03%	24.26	3.77%	24.50	4.79%	24.82	6.16%	24.86	6.33%	24.41	4.42%	23.80	1.82%
		TXn	°C	26.73	27.41	2.52%	26.52	-0.80%	27.04	1.16%	28.04	4.89%	28.69	7.32%	29.15	9.03%	27.74	3.78%	26.55	-0.68%
Precipitation indices	Threshold indices	FD	days	0.00	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
		ID	days	0.00	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Other index	SU25	days	29.32	29.19	-0.45%	28.94	-1.31%	29.11	-0.73%	28.75	-1.97%	28.62	-2.40%	29.18	-0.49%	29.28	-0.15%	28.86	-1.56%
		TR	days	14.46	17.31	19.65%	17.05	17.84%	17.73	22.57%	18.14	25.37%	19.61	35.58%	19.43	34.33%	19.27	33.21%	17.09	18.16%
	Intensity indices	DTR	°C	12.18	11.94	-1.93%	11.97	-1.67%	11.94	-1.94%	12.06	-0.93%	11.94	-1.95%	11.96	-1.75%	11.45	-5.99%	11.69	-3.99%
		R20mm	days	0.14	0.14	2.73%	0.21	49.40%	0.44	217.37%	0.19	35.71%	0.14	2.01%	0.10	-28.09%	0.22	62.02%	0.13	-6.09%
		Rx5day	mm	10.84	12.67	16.90%	16.51	52.37%	22.73	109.77%	13.33	23.06%	13.09	20.78%	8.87	-18.11%	16.13	48.88%	13.63	25.80%
		PRCPTOT	mm	11.94	17.18	43.91%	20.48	71.55%	32.08	168.69%	18.51	54.99%	17.10	43.18%	11.65	-2.43%	22.36	87.29%	16.30	36.49%
Other indices	CDD	days	29.04	24.10	-17.00%	24.53	-15.52%	22.09	-23.94%	24.16	-16.80%	23.50	-19.08%	28.04	-3.43%	22.04	-24.11%	24.01	-17.31%	
	CWD	days	0.91	1.60	74.94%	1.88	105.96%	1.71	87.13%	1.47	61.09%	1.57	72.08%	1.13	23.70%	1.59	74.74%	1.53	67.55%	

Table 3.22 Autumn percentage change of climate indices.

Category	Index	Unit	Baseline	AUTUMN												% change	Model 3-1	% change	Model 3-2	% change	Model 3-3	% change	Model 4-1	% change	Model 4-2	% change
				Model 1-1	% change	Model 2-1	% change	Model 2-2	% change	Model 3-1	% change	Model 3-2	% change	Model 3-3	% change	Model 4-1	% change	Model 4-2	% change							
Temperature indices	Percentile-based indices	TX10	%	11.15	-5.09%	10.34	-7.26%	10.55	-5.39%	9.83	-11.89%	10.57	-5.21%	9.81	-12.07%	10.22	-8.40%	10.65	-4.49%							
		TX90	%	9.18	7.61%	9.71	5.82%	10.15	10.60%	9.76	6.33%	10.06	9.63%	9.54	3.98%	9.48	3.25%	9.62	4.86%							
		TN10	%	10.19	-11.66%	10.05	-1.35%	10.37	1.81%	8.59	-15.71%	10.47	2.82%	8.95	-12.18%	10.30	1.13%	10.29	1.00%							
		TN90	%	9.75	-2.27%	9.84	0.96%	10.07	3.31%	9.57	-1.81%	10.04	2.99%	9.60	-1.50%	9.99	2.46%	10.15	4.14%							
	Absolute indices	TXx	°C	29.25	4.55%	30.58	4.53%	30.75	5.10%	30.83	5.41%	31.27	6.91%	29.83	1.98%	30.09	2.88%	30.17	3.14%							
		TNn	°C	4.48	62.70%	7.78	73.77%	8.32	85.78%	7.81	74.40%	9.22	105.88%	7.45	66.30%	8.10	80.73%	6.96	55.27%							
		TNx	°C	17.32	5.31%	18.53	6.96%	19.30	11.42%	18.59	7.35%	18.59	7.34%	18.12	4.63%	18.51	6.85%	18.12	4.60%							
		TXn	°C	16.18	5.60%	17.39	7.45%	17.50	8.14%	17.43	7.69%	18.51	14.40%	16.96	4.82%	17.53	8.31%	16.58	2.46%							
	Threshold indices	FD	days	0.93	5.66%	0.53	-42.77%	0.42	-54.92%	0.78	-15.37%	0.48	-48.03%	0.94	1.18%	0.60	-35.34%	0.67	-27.33%							
		ID	days	0.01	15.36%	0.01	-41.19%	0.02	105.83%	0.02	42.50%	0.01	-36.67%	0.03	214.40%	0.00	-59.29%	0.00	-90.95%							
		SU25	days	12.86	15.66%	15.13	17.64%	15.42	19.90%	14.95	16.24%	16.24	26.22%	13.87	7.82%	14.45	12.36%	13.23	2.86%							
		TR	days	2.18	58.37%	3.74	71.88%	4.27	96.12%	4.15	90.30%	5.56	155.21%	3.56	63.56%	4.45	104.07%	3.48	59.65%							
Precipitation indices	Other index	DTR	°C	11.40	-1.37%	11.32	-0.64%	10.95	-3.96%	11.26	-1.17%	11.19	-1.85%	11.04	-3.10%	10.59	-7.11%	10.94	-4.00%							
		R20mm	days	0.95	-23.81%	0.87	-9.15%	1.00	5.09%	0.96	0.41%	0.82	-14.49%	0.99	3.29%	1.24	29.70%	0.91	-4.88%							
		Rx5day	mm	43.82	-14.81%	40.70	-7.12%	44.07	0.58%	42.69	-2.56%	37.79	-13.75%	46.26	5.57%	51.27	17.01%	43.04	-1.77%							
		PRCPTOT	mm	62.32	-14.80%	64.18	2.97%	70.13	12.53%	65.07	4.41%	58.32	-6.42%	67.37	8.09%	85.76	37.60%	65.84	5.64%							
	Indices	CDD	days	36.59	-21.24%	26.14	-28.55%	22.87	-37.50%	17.07	-53.35%	16.81	-54.07%	17.83	-51.27%	21.53	-41.15%	31.22	-14.66%							
		CWD	days	2.32	18.51%	3.02	30.33%	3.29	41.88%	2.81	21.40%	2.90	25.22%	3.07	32.64%	3.42	47.76%	2.65	14.47%							

Table 3.23 Winter percentage change of climate indices.

Category	Index	Unit	Baseline	WINTER												% change	Model 4-2	% change	% change
				Model 1-1	% change	Model 2-1	% change	Model 2-2	% change	Model 3-1	% change	Model 3-2	% change	Model 3-3	% change	Model 4-1	Model 4-2	% change	% change
Temperature indices	TX10	%	10.54	9.51	-9.83%	10.49	-0.48%	10.45	-0.89%	9.06	-14.03%	10.14	-3.79%	9.43	-10.52%	8.81	10.71	-16.40%	1.61%
	TX90	%	10.35	9.78	-5.54%	10.19	-1.51%	10.25	-1.00%	9.53	-7.96%	9.69	-6.42%	9.62	-7.07%	9.82	9.48	-5.13%	-8.43%
	TN10	%	10.52	9.47	-10.00%	10.49	-0.29%	10.36	-1.48%	9.48	-9.90%	10.14	-3.60%	9.31	-11.49%	10.36	10.69	-1.48%	1.67%
	TN90	%	10.21	9.78	-4.21%	10.38	1.70%	10.38	1.73%	9.70	-4.98%	9.87	-3.31%	9.39	-7.98%	9.98	9.91	-2.20%	-2.92%
	TXx	°C	18.49	18.07	-2.27%	17.79	-3.79%	17.91	-3.10%	18.95	2.50%	19.34	4.63%	18.64	0.85%	18.28	18.43	-1.11%	-0.32%
Threshold indices	TNn	°C	-3.85	-2.29	-40.54%	-2.03	-47.26%	-1.34	-65.13%	-1.06	-72.55%	0.13	-103.42%	-0.74	-80.78%	-0.92	-0.70	-76.11%	-81.90%
	TNx	°C	10.24	10.31	0.66%	10.25	0.09%	11.06	7.99%	10.99	7.26%	11.30	10.31%	11.07	8.02%	11.13	10.99	8.63%	7.23%
	TXn	°C	6.07	5.29	-12.84%	5.53	-8.95%	5.61	-7.61%	6.59	8.61%	8.04	32.41%	7.37	21.43%	7.33	6.92	20.72%	14.03%
	FD	days	6.05	6.82	12.80%	6.22	2.81%	5.47	-9.52%	5.35	-11.52%	3.49	-42.32%	5.26	-13.10%	4.89	4.80	-19.12%	-20.60%
Other index	ID	days	0.37	0.71	90.27%	0.54	43.53%	0.48	27.70%	0.39	4.02%	0.24	-35.28%	0.34	-9.12%	0.26	0.34	-30.45%	-9.86%
	SU25	days	0.02	0.03	36.05%	0.03	39.53%	0.02	-20.93%	0.05	138.37%	0.23	956.98%	0.04	70.93%	0.03	0.03	16.28%	48.84%
	TR	days	0.00	0.00	-100.00%	0.00	-100.00%	0.00	800.00%	0.00	-50.00%	0.17	34850.00%	0.00	-100.00%	0.00	0.00	-50.00%	-50.00%
	DTR	°C	8.74	8.07	-7.72%	8.21	-6.08%	8.17	-6.55%	8.46	-3.22%	8.31	-4.90%	8.40	-3.93%	8.29	8.21	-5.14%	-6.09%
Precipitation indices	R20mm	days	1.64	1.75	6.70%	1.66	1.57%	1.69	3.52%	1.38	-15.84%	1.71	4.34%	1.59	-2.68%	1.33	1.56	-18.65%	-4.71%
	Rx5day	mm	62.74	63.54	1.28%	62.15	-0.94%	61.46	-2.04%	56.33	-10.21%	59.70	-4.85%	60.47	-3.61%	52.99	59.79	-15.54%	-4.71%
	PRCPTOT	mm	107.96	120.78	11.87%	121.10	12.17%	116.83	8.21%	100.39	-7.01%	114.87	6.40%	106.99	-0.90%	97.75	112.21	-9.46%	3.93%
	CDD	days	12.50	10.99	-12.08%	9.66	-22.72%	9.96	-20.35%	10.39	-16.88%	9.89	-20.88%	11.15	-10.82%	10.77	10.23	-13.86%	-18.11%
Other indices	CWD	days	3.66	5.19	41.63%	4.74	29.41%	4.50	22.80%	4.10	11.84%	4.56	24.56%	4.09	11.67%	4.28	4.14	16.83%	13.09%