ISTANBUL TECHNICAL UNIVERSITY ★ EURASIA INSTITUTE OF EARTH SCIENCES

TREND ANALYSIS OF
CLIMATE EXTREME INDICES
FOR TURKEY

M.Sc. THESIS

Berna DÜNDAR

Department of Climate and Marine Sciences

Earth System Science Programme

JANUARY 2015

ISTANBUL TECHNICAL UNIVERSITY ★ EURASIA INSTITUTE OF EARTH SCIENCES

TREND ANALYSIS OF CLIMATE EXTREME INDICES FOR TURKEY

M.Sc. THESIS

Berna DÜNDAR
(601111003)

Department of Climate and Marine Sciences

Earth System Science Programme

Thesis Advisor: Prof. Dr. Ömer Lütfi ŞEN

JANUARY 2015

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ AVRASYA YER BİLİMLERİ ENSTİTÜSÜ

TÜRKİYE’DE İKLİM UÇ OLAYLARI İNDİSLERİNİN TARİHSEL DEĞİŞİMİ

YÜKSEK LİSANS TEZİ

Berna DÜNDAR
(601111003)

İklim ve Deniz Bilimleri Anabilim Dalı

Yer Sistemi Bilimi Programı

Tez Danışmanı: Prof. Dr. Ömer Lütfi ŞEN

OCAK 2015

Berna Dündar, a **M.Sc.** student of ITU **Eurasia Institute of Earth Sciences** student ID **60111003**, successfully defended the **thesis** entitled "**TREND ANALYSIS OF CLIMATE EXTREME INDICES FOR TURKEY** ", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Prof. Dr. Ömer Lütfi ŞEN** ....
İstanbul Technical University

Jury Members : **Prof. Dr. Nüzhet Dalfes** ....
İstanbul Technical University

Assoc. Prof. Dr. M. Akif Sarıkaya ....
İstanbul Technical University

Date of Submission : **9 December 2014**
Date of Defense : **20 January 2015**

To my family,

FOREWORD

This study intended to assess the climate extremes indices effects on Turkey. It was conducted nearly one and a half year at the Istanbul Technical University, Eurasia Institute of Earth Sciences. This thesis owes thanks to many people for their supportins.

First of all, I would like to thanks my supervisor Prof. Dr. Ömer Lütfi Şen. I would also like to thanks Dr. Ozan Mert Göktürk. He supported to me throughout the whole study.

I would express my thanks to my dear friends Dr. Tuğba Öztürk from Işık University and Ayşe Savcı. I would also express my special thanks to Şükrü Murat Cebeci.

January 2015 Berna DÜNDAR

TABLE OF CONTENTS

Page

ABBREVIATIONS

AEG	**:** Aegian Region
BLS	**:** Black Sea Region
CAN	**:** Central Anatolia Region
CLIVAR	**:** Climate and Ocean Variability, Predictability, and Change Team
DTR	**:** Daily Temperature Range
FD	**:** Number of Frost Days
ETCCDI	**:** The joint CCI/CLIVAR JCOM Expert Team on Climate Change
	: Detection and Indices
ID	**:** Number of Icing Days
MAR	**:** Marmara Region
MED	**:** Mediterrean Region
NaN	**:** Missing Values
NCL	**:** Ncar Command Language
SAN	**:** South Anatolia Region
SU	**:** Number of Summer Days
TNx	**:** Monthly Maximum Value of Daily Minimum Temperture
TNn	**:** Monthly Minimum Value of Daily Minimum Temperature
TR	**:** Number of Tropical Nights
TXn	**:** Monthly Minimum Value of Daily Maximum Temperature
TXx	**:** Monthly Maximum Value of Daily Maximum Temperature
WMO	**:** World Meteorological Organization

LIST OF TABLES

Page

LIST OF FIGURES

Page

TREND ANALYSIS OF CLIMATE EXTREME INDICES FOR TURKEY

SUMMARY

The climate system has a profound effect on life on the Earth. People's daily life mainly depends on weather that surrounds them. Besides, wheather and climate extremes have significant influence on society, environment and the economy. Hence, it is very important to study them.

ETCCDI defined 27 core indices for investigating extreme events. In this study 14 indices from them has been analysed. Daily temperature and precipitation data for 452 stations, obtained from Turkish State Metereological Service. In order to eliminate stations with missing values, data visualization method used and 134 stations selected from 452 stations. These data were used for trend analysis of these indices between the periods 1965 – 2006.

The Sequentiall Mann Kendall non-parametric test applied for trend analysis of the indices. This version of the Mann Kendall test used to determine the beginning of a trend within a sample.

Firstly, in this study annual maximum and minimum temperature trends examined for four months that were October, May, January and July. In addition, their annual precipitation investigation have been done. According to this examination, annual maximum temperatures of July', October and May showed increasing trends whereas there was not any spatially coherent trend observed for January. Annual minimum temperature investigation revealed that for July' there was spatially coherent increasing trend throughout the country. In contrast, just one station indicated decreasing trend that was Erzurum. Moreover, the same behavior observed for October' annual minimum temperatures also. Annual minimum temperatures for May' indicate both increasing and decreasing trends for some stations. There was not any annual precipitation pattern found for these months.

Secondly, trend analysis of 14 indices studied. According to this analysis, there was no spatially coherent increasing or decreasing trend for "number of frost days", though the few stations that indicate increasing behaviour were mainly in the northern half of the country. On the other hand, "numbers of summer days" have been increasing in Turkey; and the significant increases distributed throughout the country with the exception of Southeastern Anatolia region. For "tropical nights", stations located around the Marmara Sea, Mediterranean coastal areas and northeast of the country showed increasing trends. There weren't any trends observed for "growing season length" and "icing days".

Trend analysis of monthly maximum temperatures of daily maximum and minimum, monthly minimum temperatures of daily maximum and minimum have been done for January and July. No trends observed for January. However, there was an increasing trend for monthly maximum value of daily minimum temperatures of July. This trend observed along coastal areas, especially Aegean and Mediterranean regions and some

stations around Marmara Sea. Furthermore, a few stations on the Black Sea coastline and some inland stations showed this behavior also.

Trend analysis of monthly minimum value of daily maximum temperature of July indicated an increasing trend along the Mediterranean and Aegean coastlines. Besides, the same behavior observed at some stations located in the Southeast, Central Anatolia and northeast of the Black Sea Region.

Trend analysis of monthly minimum value of daily minimum temperature of July showed an increasing trend along the Mediterranean, Aegean coastlines and some stations around Marmara Sea. Moreover, some stations in the west, central and northern part of the country.

Trend analyses of daily temperature range done for January and July. For January, there wasn’t any spatially coherent trends observed; some stations showed decreasing; some Aegean coastline and inland stations indicated increasing trend.

Trend analyses of July showed that stations mainly in the northern part of the country indicated increasing trend wheras some stations located in the Mediterraean coastal areas and southeast and east part of the country showed decreasing behavior.

Trend analyses of precipitation indices were done as well. However, there wasn’t any trend observed for monthly maximum 1-day precipitation, also monthly maximum consecutive 5-day precipitation. Moreover, no trend observed for R10mm (annual count of days when precipitation ≥ 10 mm) and R20mm.

In this study, 134 stations annual maximum and minimum temperature and precipitation data have been analysed for the period 1965-2006. In addition, 14 climate extreme indices trends have been investigated for the same period. Consequences from this research revealed that; annual maximum temperature of July, October and May indicated increasing trends. Besides, annual minimum temperature of July and October showed increasing tendency throughout the country. However, there wasn’t any precipitation pattern found for Turkey. In addition, increasing trend observed for number of summer days and tropical nights whereas there weren’t any spatially coherent trends observed for growing season length and icing days. Monthly maximum and minimum temperatures displayed increasing trend for July. However, no trends observed for January. Hence, it may infer that the effect of climate change on Turkey is more obvious in the warmer part of the year.

TÜRKİYE’DE İKLİM UÇ OLAYLARI İNDİSLERİNİN TARİHSEL DEĞİŞİMİ

ÖZET

Dünya üzerindeki hayat, hava durumu ve iklim olaylarından ciddi şekilde etkilenmektedir. İklimin su kaynakları, tarım, sağlık, yaşam koşulları, ekonomi, toplum ve çevrenin üzerindeki etkisi kaçınılmazdır. Dolayısıyla, iklimdeki değişkenliği ve bunun olası etkilerini anlayabilmek gerekir. Bunun için de öncelikle iklim sistemi hakında temel bir fikre sahip olunmalıdır.

Hava durumu belirli bir zaman ve yer için atmosferdeki değişimleri ifade eder. Örneğin, sıcaklık, yağış, bulutlanma, rüzgâr, nem gibi atmosferik parametrelerin değişimi hava durumunun nasıl olduğunu ve kısa süreli olarak (birkaç gün veya hafta) içinde nasıl değişeceğini gösterir. Hava durumu tahminleri ancak bir kaç gün veya maksimum iki hafta olacak şekilde yapılabilir.

Bir bölgenin iklimi ise on yıllar üzerinden gözlenen hava durumlarının ortalaması olmakla beraber burada değişkenliklerin ve uç olayların da hesaba katılması gerekir.

Dünya üzerinde iklim bölgesel olarak değişiklikler gösterir. Burada topoğrafya ve enlem farkı önem arz eder. İklim ayrıca zamana bağlı olarak da değişim gösterir. Bu zaman ölçeği onlarca yıldan milyonlarca yıla kadar değişebilir. İklim değişkenliği doğal bir süreç olmakla beraber günümüzde bu durum insan etkisiyle meydana gelen iklim değişikliğinden dolayı ciddi anlamda önem kazanmaktadır. Bunun sonuçları yeryüzündeki hayatı önemli şekilde yüzyıllar boyunca etkileyecek kapasitededir. Özellikle günlük hayatı olumsuz yönde etkileyen uç olayların oluşumunun artması da bu insan kaynaklı iklim değişikliğinin sonuçlarındandır.

Maksimum, minimum ve ortalama sıcaklık değerleri, yağış miktarı hava durumunu belirleyen iklim parametreleridir. Fakat kuraklık, sel, sıcak hava dalgası gibi istatistiksel olarak oluşma olasılığı az olan durumlar uç olaylar olarak nitelendirilir. Bunların yoğunluk ve oluşum sıklıkları toplumu, çevreyi ve ekonomiyi olumsuz bir şekilde etkilemektedir. Örneğin, daha yüksek maksimum sıcaklıklar; sıcak hava dalgalarına ve karasal alanlar üzerinde daha çok sıcak günlerin oluşumuna neden olabilir. Aynı şekilde, şiddetli yağış olaylarının sıklığının artışı; taşkınların, heyelanların, toprak erozyonlarının artışına neden olur. Bunlar, günlük hayatın birçok anlamda zorlaşmasına sebep olurlar. Dolayısıyla uç olayların bilimsel olarak incelenmesi ve gerekli tedbirlerin önceden alınabilme olasılığının arttırılması bu konuda hassas olan çevre, toplum ve ekonomi için büyük önem arz etmektedir.

Bu çalışmalardan bir tanesi de WMO ve CLIVAR ortak iklim değişikliği belirleme, görüntüleme ve indis uzman grubu ETCCDI tarafından yapılmıştır. Bu çalışmada uç olayların analizi için günlük maksimum, minimum sıcaklık ve yağış verilerinden türemiş 27 çekirdek indis oluşturulmuştur. Örneğin yaz günleri ve tropik geceler sayısı ya da buz ve donlu günler sayısı gibi.

Bu tez çalışmasında ETCCDI tarafından hazırlanan 27 indis referans olarak alınmıştır. Türkiye için 14-iklim indisinin 1965 – 2006 yılları arasındaki eğilimi incelenmiştir. Bu analizin yapılması esnasında kullanılan günlük maksimum ve minimum sıcaklık ve yağış verileri Türkiye Meteoroloji Genel Müdürlüğü'nden 452 istasyon için temin edilmiştir. Veri görselleştirme metodu ile tam veriye sahip olan 134 istasyon seçilmiş ve belirtilen dönem için analizler tamamlanmıştır.

Analizi yapılan indisler: donlu günler, yaz günleri, buz günleri ve tropik geceler sayısı, büyüme sezonu uzunluğu, Ocak ve Temmuz ayları için maksimum sıcaklıkların maksimumu, minimum sıcaklıkların maksimumu, maksimum sıcaklıkların minimumu, minimum sıcaklıkların minimumu ve günlük sıcaklık aralığı değerleridir. Günlük maksimum yağış miktarı, 5 günlük ardışık maksimum yağış miktarı ve yağışın 10 ve 20 mm'den büyük olduğu günlere ait indisler için ayrıca tek tek hesaplamalar yapılmıştır.

Yöntem olarak parametrik olmayan Mann Kendall sıra korelasyon testi uygulanmıştır. Bu test nonparametrik olduğundan verilerin dağılımından bağımsızdır. Bu metoda göre, testin uygulandığı zaman serisinde bir artış veya azalma olup olmadığı sıfır hipotezi ile yani 'H0: eğilim yok' ile belirlenir. Grafiksel olarak ifade edilen test sonucuna göre de eğilimin başlangıç yılı tespit edilir.

Bu metotta orijinal gözlem değerleri yerine sıralı dizideki değerler kullanılarak test istatistiği t_i değeri hesaplanır. Test istatistiği t_i nin dağılımı, sıfır hipotezi altında yaklaşık normaldir. Daha sonra dağılım fonksiyonun ortalaması ve varyansı bulunur. Bunlar kullanılarak sınama örneklem değeri $u(\mathrm{t})$ ve $u'(\mathrm{t})$ değerleri hesaplanır. İstenilen anlamlılık düzeyine göre eğer $u(\mathrm{t}) > 0$ ise artan, değilse ($u(\mathrm{t}) < 0$) azalan yönde bir eğilimin olduğu anlaşılır. Örneğin %5 anlamlılık düzeyinde $-1.96 < u(t) < +1.96$ için herhangi bir eğilim yoktur denir. Yani $u(\mathrm{t})$ değeri bu sınırlar içinde kalıyorsa herhangi bir trend olmadığı anlaşılır. Fakat bu sınırları artan ya da azalan yönde aştığında istatistiksel açıdan önemli bir trendin varlığından söz edilir. Trendin başlangıç yılı $u(\mathrm{t})$ ve $u'(\mathrm{t})$ grafiklerinin birbirini kestiği noktadan itibarendir. Ayrıca grafikler birçok noktada birbirini kesiyorsa yine herhangi bir trendin varlığından bahsedilemez.

Bu çalışmada parametrik olmayan Mann Kendall sıra korelasyon testi 134-istasyon için uygulanmıştır.

İlk olarak, Ocak, Temmuz, Ekim ve Mayıs aylarının yıllık maksimum ve minimum sıcaklık ve yağış analizleri tamamlanmıştır. İncelenen dönemde bu ayların verileri tam olduğundan dolayı bu aylar seçilmiştir. Bu analizlerin sonuçları şu şekildedir. Mayıs, Temmuz ve Ekim ayları için yıllık maksimum sıcaklıklarda artış gözlemlenmiştir. Ocak ayı için ise mekânsal uyumluluk arzeden herhangi bir trende rastlanmamış bazı istasyonlarda artış, bazılarında ise azalma görülmüştür. Temmuz ve Ekim aylarının yıllık minimum sıcaklıkları eğilimi mekânsal olarak uyumlu bir artış göstermiş sadece Erzurum istasyonunda azalma görülmüştür. Mayıs ayı minimum sıcaklıkları için hem azalış hem artış gösteren istasyonlar mevcuttur. Yıllık yağış eğilim analizinde ise herhangi bir trende rastlanmamıştır.

14 indis için 1965 – 2006 yılları arasında yapılan analiz sonuçları ise şu şekilde bulunmuştur. Donlu günler (FD) minimum sıcaklığın 0°C'den küçük olduğu günler sayısını göstermektedir. Bu indisin analiz sonucu mekânsal olarak anlamlı bir artış ya da azalış eğilimi göstermemekle birlikte, kuzey kesimde bazı istasyonlarda bu günler için artış görülmektedir.

Maksimum sıcaklığın 25°C'den büyük olduğu günler yaz günleri, SU, olarak tanımlanmaktadır. Yaz günleri sayısıyla ilgili olarak incelenen indis sonucuna göre, bu günlerin sayısında ülke genelinde Güneydoğu ve Doğu Anadolu bölgeleri hariç olmak üzere, istatistiksel olarak anlamlı bir artış görülmektedir.

Tropik geceler minimum sıcaklığın 20°C'den büyük olduğu güne tekabül etmektedir. Bu indis için bulunan sonuçlara göre, Marmara Deniz'i çevresi ve Akdeniz kıyılarında bulunan istasyonlar ile kuzeydoğu Karadeniz'de bulunan istasyonlarda bu günlerde artış mevcuttur. Ayrıca Güneydoğu ve Doğu Anadolu bölgelerinde yer alan örneğin; Malatya, Bingöl, İspir, Keban, Siirt, Ceylanpınar, Samandağ ile Ege Bölgesi'nde Çeşme, Denizli, Bodrum, Selçuk istasyonlarında da minimum sıcaklığın 20°C'den büyük olduğu günlerde artış gözlemlenmiştir.

Günlük maksimum sıcaklıkların aylık maksimum ve minimum değeri ve günlük minimum sıcaklıkların aylık maksimum ve minimum değerleri Ocak ve Temmuz ayları için incelenmiştir. Ocak ayları için herhangi bir eğilim bulunmamakla birlikte Temmuz ayları için gözlemlenen eğilimler şu şekildedir: Günlük minimum sıcaklıkların aylık maksimum değeri için Ege ve Akdeniz kıyıları ile Marmara Denizi çevresindeki istasyonlarda, iç kesimde yer alan bazı istasyonlar ile Karadeniz kıyısındaki birkaç istasyonda artış görülmektedir. Günlük maksimum sıcaklıkların aylık minimum değerleri için Ege ve Akdeniz kıyıları ile Güneydoğu, İç Anadolu ve kuzeydoğu Karadeniz'de ki bazı istasyonlarda artış görülmüştür. Günlük minimum sıcaklıkların aylık minimum değeri için Ege ve Akdeniz kıyıları, Marmara Denizi çevresindeki istasyonlar ile ülkenin batı, iç ve kuzey kısımlarında yer alan bazı istasyonlarda artış gözlenmiştir.

Günlük sıcaklık aralığı (maksimum, minimum sıcaklıkları farkı) indisi analizi Temmuz ve Ocak ayları için şu sonuçları vermektedir. Ocak ayı için herhangi bir mekânsal uyumluluk görülmemekle beraber bazı istasyonlarda azalan, bazı iç istasyonlarda ise artan değerler mevcuttur. Örneğin, İnebolu, Giresun, Bafra, Silifke, Çankırı, Nevşehir, Ardahan, Van, Sarıkamış, Kireçburnu istasyonların da eğilim azalma yönündedir. Antalya, Dikili, Bodrum, Burdur gibi istasyonlarda da artış görülmektedir. Temmuz ayı için ise günlük maksimum, minimum sıcaklık farkları kuzeyde bulunan istasyonlarda artış, Akdeniz kıyı kesiminde ve güneydoğu ve doğuda bulunan bazı istasyonlarda ise azalış şeklinde görülmektedir.

Buz günleri (ID) maksimum sıcaklığın 0°C'den küçük olduğu günler için analiz sonuçlarında herhangi bir eğilim bulunamamıştır.

Bütün bu sonuçlara göre yani günlük maksimum ve minimum sıcaklık verileri kullanılarak yapılan analiz sonuçlarına göre, Türkiye üzerinde iklim değişikliğinin etkilerinin özellikle yılın sıcak dönemlerinde daha belirgin olduğu anlaşılmıştır.

Büyüme sezonu uzunluğu (GSL) günlük ortalama sıcaklığın 5°C'den büyük olduğu ilk 6 gün ile günlük ortalama sıcaklığın 5°C'den küçük olduğu ilk 6 gün arasındaki günler toplamını veren indis için de herhangi bir eğilim görülmemekle beraber, kıyı kesimlerinde bu sürenin 365 günü geçtiği dönemler olmuştur. Örneğin Samandağ istasyonunda 1965, 1980, 2000 yıllarında günlük ortalama sıcaklık 365 gün boyunca 5°C'nin altına düşmemiştir.

Bir ay içindeki günlük maksimum yağış miktarı, 5 günlük ardışık maksimum yağış miktarı, yağışın 10 mm'den (şiddetli yağışlı) ve 20 mm'den (çok şiddetli yağışlı) fazla olduğu günler sayısıyla ilgili analizleri yapılan indisler için Ocak, Temmuz, Mayıs ve Ekim ayları için herhangi bir eğilime rastlanmamıştır.

Bu çalışmada, 134 istasyon için yıllık maksimum ve minimum sıcaklık ve yağış verileri ile 14 iklim indisinin eğilim analizi 1965-2006 yılları için yapılmıştır. Yapılan araştırmanın sonuçları göstermektedir ki; yıllık maksimum sıcaklıklar için Temmuz, Ekim ve Mayıs aylarında Türkiye genelinde bir artış mevcuttur. Aynı şekilde yıllık minimum sıcaklık değerleri Temmuz ve Ekim ayları için artış göstermektedir. Yaz günleri ve tropik geceler sayısında artış olmakla beraber, büyüme sezonu uzunluğu ve buz günlerinde herhangi bir eğilime rastlanmamıştır. Ülke genelinde yağış deseni için de herhangi bir eğilim mevcut değildir. Aylık maksimum ve minimum sıcaklık değerleri Temmuz aylarında artış göstermekte fakat Ocak ayları için herhangi bir eğilim bulunmamaktadır. Sonuç olarak ülke çapında maksimum ve minimum sıcaklıkları etkileyen bir ısınma eğilimi olmakla beraber, yağış için herhangi bir eğilim bulunamamıştır.

1. INTRODUCTION

Weather and climate have significant effect on life on the Earth. People's daily life mainly depends on the interactions between the components of the climate system. Effect of weather and climate on water resources, food production, health, and welfare is inevitable. In this manner, variations in climate are very important for society and the environment. Hence, in order to understand the variation in climate and its results on nature and society, first we should understand the climate system.

Ahrens (2007) explained that the condition of the atmosphere at any particular time and space called weather. Atmospheric conditions are affected by some parameters, such as air temperature, air pressure, precipitation, clouds, wind, humidity and visibility. Furthermore, weather can be predicted only for a limited time scale such as several days or a week (IPCC, 2001).

Ahrens (2007) also stated that the climate of a region is the average state of its weather over a longer period that is months or years. Besides, it includes the extremes of weather such as heat waves or warm spells for a particular region. The Thirth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) indicated that there are many kinds of climatic regimes observed on the Earth, which varies from region to region. Moreover, a geographical factor, for example, mountains, lake or sea, vegetation type and latitude affect the climate system. In addition, climate varies in time scales. It changes from season to season, year to year, decade to decade.

Taylor (2005) stated that the climate system consists of the Earth that is land, ocean and ice, the surrounding atmosphere, radiation from the Sun and their interactions. The Sun considered as an external forcing mechanism of the system. The radiation coming from the Sun is the main source of the climate system that drives it. Houghton (2004) explained this driving mechanism of the system as; outside of the atmosphere, which directly facing the Sun, receives 343 watts radiant energy per square meter. Six percent of this amount reflected back to space by atmospheric molecules. Furthermore, ten percent of this radiation scattered from the land and ocean surface to the space. Eighty-four percent of this energy that is 288 watts per square meter is used for heating the surface of the Earth. In order to maintain a stable climate there should be an energy balance between incoming and outgoing solar radiation. As a result, 288 Wm^{-2} radiations should be emitted back into space.

IPCC (2001) pointed out that half of the solar radiation coming from the Sun is in the visible short wave part of the electromagnetic spectrum. The other is mostly in the form of near infrared and ultraviolet radiation. By contrast, heat that returns from the Earth's surface to the atmosphere is in infrared part. The average net radiation at the top of the atmosphere is zero when the climate system is in equilibrium condition, which means incoming and outgoing radiation is equal. However, if a change in solar radiation or the infrared radiation happens then, an imbalance occurs that is called radiative forcing. Variations in radiative forcing may be due to external forcings such as solar radiation or aerosols or anthropogenic effect that leads to change in the atmospheric composition.

One of the natural forcing of the climate system is greenhouse gases, which are parts of the atmosphere naturally. These gases have an important role in the energy balance of the climate system due to absorbing and emiting infrared radiation (IPCC, 2001). Kump et al. (2004) said that water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and chlorofluorocarbons (CFCs) are main greenhouse gases. Lutgens et al. (2010) assessed that they affect energy balance of the climate system. Short wave radiation that comes from the Sun passes through the atmosphere and comes to Earth's surface. It re-radiated from the land-sea surface as a long-wave radiation and absorbed by water vapor, carbon dioxide and other trace gases in the atmosphere. Then, this radiation sent back to the Earth surface again so heat is held within the atmosphere. This process is called the natural greenhouse effect.

IPCC (2001) reported that before the Industrial Revolution, the total greenhouse gases in the atmosphere remained constant. However, when human activities have begun to increase then the gases concentration increased also, which leads to intensify the absorption and emission of the infrared radiation. Thus, positive radiative forcing occurs that result in warming of the surface on average. As a result, enhanced greenhouse effect is observed.

IPCC (2001) also stated that natural variability of climate depends on external forcing and the interactions within the system components. For example, the contingency of extreme events may be due to radiative forcing. The weather and climate parameters such as maximum, minimum and average temperature, amount of precipitation specifies the weather events. However, events such as, droughts, flooding, heat waves have the least likely occurrence in a statistical point of view. As a result, they are called extreme events. Their intensity and frequency have profound consequences on people daily life with respect to social, economical and environmental aspects. Both nature and society are vulnerable for such situations. Hence, there are some studies on this subject.

One of these researches done by ETCCDI and a core set of 27 descriptive indices of extremes has defined by using daily temperature and precipitation values (Url-1).

1.1 Purpose of Thesis

The main objective of this study is to investigate 14-climate indices trend for Turkey for the period of 1965 – 2006. These indices obtained from 27 core indices of ETCCDI.

Investigated 14 indices are:

1. FD, Number of frost days: Annual count of days when TN- daily minimum temperature < 0°C.
2. SU, Number of summer days: Annual count of days when TX- daily maximum temperature > 25 °C.
3. ID, Number of icing days: Annual count of days when TX- daily maximum temperature < 0 °C.
4. TR, Number of tropical nights: Annual count of days when TN- daily minimum temperature > 20°C.
5. GSL, Growing season length: Annual (1st Jan to 31 Dec in Northern Hemisphere) count between first span of at least 6 days with daily mean temperature TG> 5°C and first span after July 1st of 6 days with TG< 5°C.
6. TXx, Monthly maximum value of Daily maximum temperature.
7. TNx, Monthly maximum value of Daily minimum temperature.

8. TXn, Monthly minimum value of Daily maximum temperature.
9. TNn, Monthly minimum value of Daily minimum temperature.
10. DTR, Daily temperature range: Monthly mean difference between TX and TN.
11. Rx1day, Monthly maximum 1-day precipitation.
12. R10mm, Annual count of days when PRCP≥ 10 mm.
13. R10mm, Annual count of days when PRCP≥ 20 mm.
14. Rx5day, Monthly maximum consecutive 5-day precipitation.

1.2 Study Area

Turkey is located between the geographic coordinates with latitudes 36° and 42° N and longitudes 26° and 45° E. The country surrounded by Black Sea to the north, Aegean Sea to the west and Mediterrean Sea to the south. Turkish Mountains are located especially on the eastern part of the country so elevation increases eastward. Besides, there are two main mountain ranges: one in the north called Black Sea Mountain range and the other Taurus Mountains in the south. Between them, there is a high central plateau. In Turkey, climatic conditions vary from region to region. However, there are three main climate types observed for the country. One of them is Mediterranean climate characterized by hot and dry summers and mild and wet winters. Aegean and Mediterranean coastal areas experienced this temperate Mediterranean climate. Continental climate observed interior of Turkey. This climatic regime is characterized by cold winters and hot summers. Precipitation occurrence is less and especially in the form of snow during the wintertime. The Black Sea coastal region has a temperate maritime climate that is warm and wet summers with cool and wet winters. This region receives considerable amount of precipitation and its eastern part has rainfall throughout the year.

Şensoy et al. (2008) indicated that the Aegean and Mediterrean areas have different precipitation pattern depending on location. Moreover, coastal areas of these regions receive greatest amount of rain during the wintertime when compered with summers. Central Anatolia gets least amount of precipitation due to mountain location. In the south Taurus Mountains, lies close to the coast and do not allow the rain clouds to puncture to the interior part. Besides, in the Eastern part, the mountains elevations passes 2500 – 3000 m. Furthermore, in the north, Caucasian Mountain and Black Sea Mountains hold the rain clouds, as a result, interior part of the coutry experienced continental climate and receives least amount of rainfall. Although the stations on the Black Sea coasts such as Rize and Hopa, receives 2,200 mm rainfall, inland stations for example Konya and Iğdır receives 250 – 300 mm rainfall annually. In addition, annual precipitation on the Aegean and Mediterrean areas changes from 580 to 1300 mm.

Şen (2013) pointed out that Turkey's mean temperature variation changes from region to region due to topographic elevation of the country. The central plateau and eastern parts are relatively cold (usually below 0 °C) during the wintertime. However, coastal areas have mild winter months because of sea effect (usually over 4°C). In summertime, the Aegean and Mediterrean coastline and southeast part of the Turkey have monthly average temperatures exceeding 25 °C. Along the Black Sea coastline, it is around 21°C. Besides, central plain and eastern highlands have temperatures well above 20°C. Hence, in a year, monthly averages of temperature values are 18°C for the Black Sea coastline, around 20°C for the Mediterrean coastline, about 23°C for the central plateau and about 30°C for the eastern parts of Turkey.

1.3 Literature Review

Fourth Assessment Report of IPCC (IPCC, 2007) stated that Mediterrean basin is one of the most vulnerable regions to climate change. Hence, there are many scientific studies on climate change and its effect on this region. Turkey is located in the eastern parts of this basin. As a result, some investigations were done for Turkey also. Şensoy et al. (2005) examined temperature and precipitation trends for Turkey. They used 100 stations for period 1971-2000. They found increasing trend for monthly maximum of daily maximum, monthly maximum of daily minimum, monthly minimum of daily maximum, and monthly minimum of daily minimum temperatures. Furthermore, they showed that number of summer days and tropical nights increased all over the country wheras number of ice and frost days decreased. Besides, growing season length showed increasing behavior except coastal areas. Their study also indicated that most inland stations showed increasing trend for diurnal temperature range. However, it decreased along the coastal stations. In addition, their study revealed that the maximum one-day and 5-days precipitation have also increased except eastern Marmara and south Anatolia region. Zhang et al. (2005) analysed the precipitation and temperature indices of 14 countries and Turkey for period 1950 – 2003. They showed that there was not a strong trend for precipitation indices such as, number of days with precipitation and maximum daily precipitation. No spatiall coherency is found for them also. Their examination on daily minimum and maximum temperatures indicated that annual maximum of daily maximum and daily minimum temperature and the annual minimum of daily maximum and daily minimum temperature have a statistically increasing trend that is spatially coherent for the whole region. In addition, number of summer days showed increasing trend also. Türkeş et al. (2002) investigated diurnal temperature trends of 70 stations in Turkey for the period between 1929 -1999. Their research indicated that, there was a significant warming of the nighttime minimum temperatures when compared with cooling in daytime maximum temperatures for many regions. Furthermore, some stations have shown significantly increasing trend for annual and seasonal daily temperature range. Another study has been done for Turkey for period 1929 – 1999 by using 70 stations data. This investigation indicated that for southern regions of Turkey, annual mean temperatures of spring and summer have increasing trend. In addition, for the northern and continental inner regions autumn and summer mean temperatures have decreasing trend. Aegean Region autumun maximum temperatures indicated decreasing trend. Some parts of the Black Sea, Marmara and Eastern Anatolia regions have negative trends for winter and autumn minimum temperatures (Türkeş et al, 2002). Kahya et al. (2006) analysed Turkish precipitation data by using 96 stations for the period 1929 to 1993. This research indicated that January, February and especially September monthly total precipitation amount showed decreasing trend while the other months indicated increasing and decresing trends. In addition, annual mean precipitation trends for western and southern of Turkey showed downward behavior.

1.4 Motivation

It is obvious that the change in the frequency or intensity of extreme climate events have significant impacts on environment and society. It is thus very crucial to investigate extreme events. Effects of extreme events on human health, economy and nature could be devastating. Human being is affected by extreme weather conditions such as, flooding, drought and heat wave more than average weather conditions. Motivation of this study is to investigate the trend in such a catastrophic weather conditions in Turkey. It could be observed in Turkey that storm, flooding and droughts usually occurred and caused loss of life and money. For example, in 2009 in Istanbul, more than 30 people has died due to flooding of Ayamama River. Therefore, it is very important to study the trends in climate extremes for Turkey region since there are very few studies in that area.

In order to investigate extreme events, we searched 14 climate extremes indices trend for Turkey for the period 1965–2006. For achieving this goal, daily temperature and precipitation data were used.

2. DATA AND METHODOLOGY

2.1 Data

In this study, daily temperature and precipitation data were used. They were obtained from Turkish State Meteorological Service for 452 stations. In order to eliminate missing value stations data visualization method was used and 134 stations selected from them. After that trend analysis of indices, have been done for period 1965-2006.

Distribution of 452-stations data is shown in Figure 2.1. This figure was obtained from number of frost day's data. Y-axis indicates years, X-axis indicates stations. Black points have data whereas white points are NaN (missing values).

Stations without any missing values have been chosen by using data visualization method. Optimization was applied for this purpose. Periods for analyzing these data were also chosen by optimization.

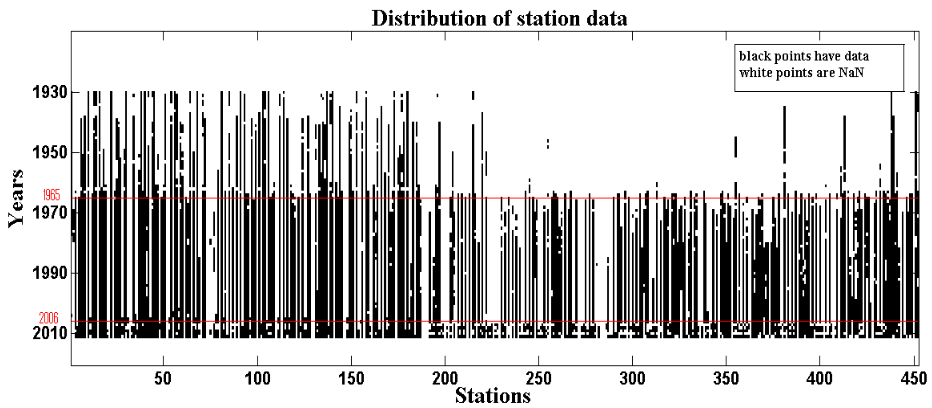

Figure 2.1 : Distribution of station data.

Stations and their missing data numbers have been shown in Figure 2.2. Some stations have 40, 45 NaN's. However, some of them do not have any missing data. Hence, stations were sorted for their missing data and its graph was shown below.

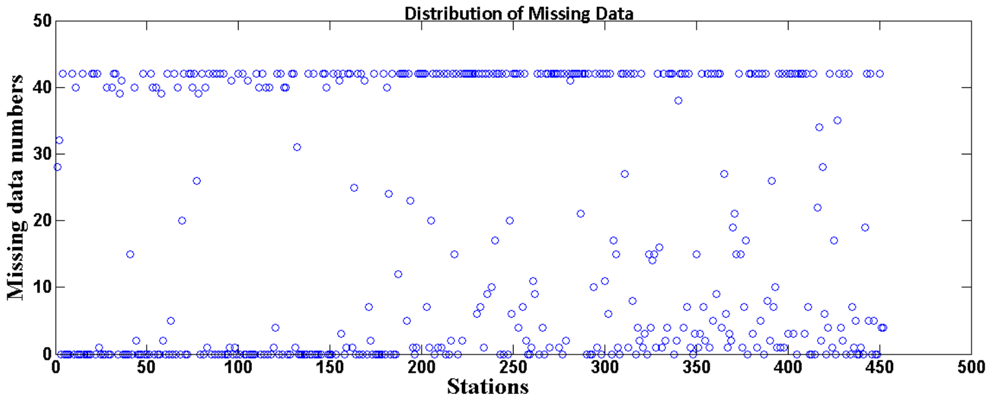

Figure 2.2 : Distribution of missing data.

Stations without any missing data indicated in Figure 2.3. In order to choose statistically meaningful period for trend analysis an optimization have been done. According to this optimization periods, 1965-2006 that is 41 years have been chosen for trend analysis of 134 stations (Figure 2.4).

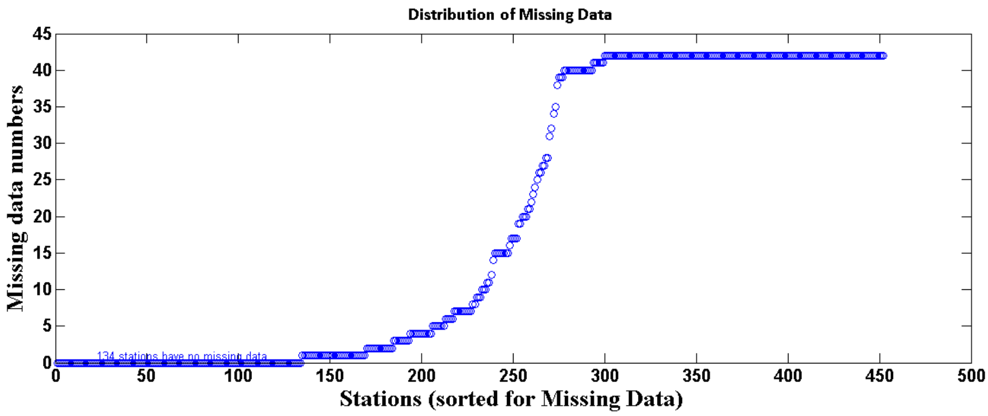

Figure 2.3 : Stations sorted for missing data.

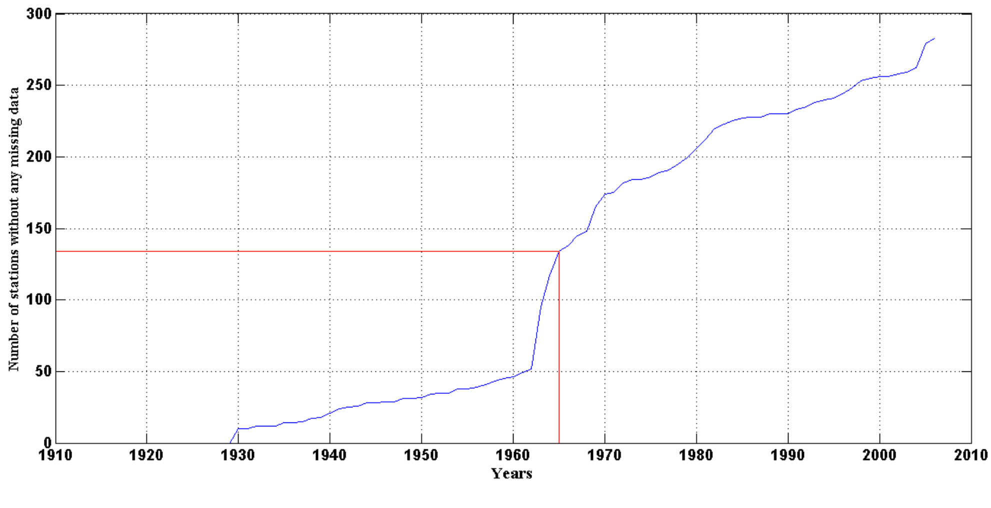

Figure 2.4 : Number of stations without missing data from 1965 to 2006.

Stations distributions according to seven regions were shown in tables below.

Table 2.1 : Black Sea region stations.

Region	Station Name	Latitude (N)	Longitude (E)
BLS	Akçakoca	41° 08'	31° 12'
BLS	Bartın	41° 60'	32° 51'
BLS	Zonguldak	41° 27'	31° 48'
BLS	İnebolu	41° 59'	33° 47'
BLS	Sinop	42° 01'	35° 10'
BLS	Samsun	41° 17'	35° 10'
BLS	Ordu	40° 81'	37° 54'
BLS	Giresun	40° 55'	38° 23'
BLS	Rize	41° 02'	40° 31'
BLS	Trabzon	41° 00'	39° 43'
BLS	Hopa	41° 24'	41° 26'
BLS	Artvin	41° 13'	41° 85'
BLS	Düzce	40° 84'	31° 16'
BLS	Kastamonu	41° 38'	33° 78'
BLS	Çorum	40° 55'	34° 95'
BLS	Amasya	40° 39'	35° 50'
BLS	Tokat	40° 18'	36° 33'
BLS	Gümüşhane	40° 27'	39° 27'
BLS	Bayburt	40° 15'	40° 14'
BLS	Bafra	41° 31'	35° 53'
BLS	Pazar-Rize	41° 10'	40° 53'
BLS	Zile	40° 28'	35° 88'

Table 2.2 : Marmara region stations.

Region	Station Name	Latitude (N)	Longitude (E)
MAR	Çorlu	41° 9'	27° 49'
MAR	Edirne	41° 40'	26° 33'
MAR	Tekirdağ	40° 59'	27° 29'
MAR	Kumköy	41° 25'	29° 04'
MAR	Kireçburnu	41° 15'	29° 05'
MAR	Göztepe	40° 58'	29° 05'
MAR	Kocaeli	40° 46'	29° 56'
MAR	Sakarya	40° 46'	30° 23'
MAR	Bolu	40° 44'	31° 36'
MAR	Gökçeada	40° 11'	25° 54'
MAR	Çanakkale	40° 8'	26° 23'
MAR	Bandırma	40° 21'	27° 58'
MAR	Bursa	40° 11'	29° 06'
MAR	Yalova	40° 39'	29° 16'
MAR	Bilecik	40° 9'	29° 58'
MAR	Edremit	39° 35'	27° 1'
MAR	Balıkesir	39° 36'	27° 55'
MAR	Uzunköprü	41° 16'	26° 41'
MAR	Lüleburgaz	41° 24'	27° 21'
MAR	Florya	40° 59'	28° 48'
MAR	Geyve	40° 31'	30° 17'
MAR	Bozöyük	39° 55'	30° 2'

Table 2.3 : Aegean region stations.

Region	Station Name	Latitude (N)	Longitude (E)
AEG	Kütahya	39° 25'	29° 58'
AEG	Dikili	39° 03'	26° 52'
AEG	Akhisar	38° 55'	27° 51'
AEG	Manisa	38° 37'	27° 27'
AEG	Uşak	38° 41'	29° 24'
AEG	Afyon	38° 45'	30° 32'
AEG	İzmir	38° 26'	27° 10'
AEG	Çeşme	38° 18'	26° 22'
AEG	Aydın	37° 51'	27° 50'
AEG	Denizli	37° 46'	29° 6'
AEG	Burdur	37° 40'	30° 20'
AEG	Bodrum	37° 02'	27° 26'
AEG	Muğla	37° 13'	28° 22'
AEG	Dalaman	36° 46'	28° 47'
AEG	Fethiye	36° 37'	29° 7'
AEG	Bergama	39° 6'	27° 10'
AEG	Bornova	38° 27'	27° 11'
AEG	Selçuk	37° 56'	27° 22'
AEG	Köyceğiz	36° 57'	28° 41'
AEG	Emirdağ	39° 1'	31° 9'

Table 2.4 : Mediterranean region stations.

Region	Station Name	Latitude (N)	Longitude (E)
MED	Alanya	36° 33'	31° 59'
MED	Antalya	36° 53'	30° 40'
MED	Anamur	36° 5'	32° 50'
MED	Silifke	36° 23'	33° 56'
MED	Mersin	36° 48'	34° 38'
MED	Adana	37° 0'	35° 19'
MED	Isparta	37° 47'	30° 34'
MED	Beyşehir	37° 67'	31° 72'
MED	İskenderun	36° 35'	36° 10'
MED	Antakya	36° 15'	36° 8'
MED	Finike	36° 18'	30° 8'
MED	Göksun	38° 1'	36° 29'
MED	Tefenni	37° 18'	29° 46'
MED	Kozan	37° 26'	35° 49'
MED	K.Maraş	37° 35'	36° 55'
MED	Karaisalı	37° 16'	35° 4'
MED	Elmalı	36° 44'	29° 54'
MED	Manavgat	36° 46'	31° 26'
MED	Dörtyol	36° 51'	36° 13'
MED	Yumurtalık	36° 46'	35° 47'
MED	Karataş	36° 34'	35° 23'

Table 2.5 : East Anatolia region stations.

Region	Station Name	Latitude (N)	Longitude (E)
EAN	Ardahan	41° 6'	42° 42'
EAN	Erzincan	39° 42'	39° 31'
EAN	Erzurum	39° 53'	41° 16'
EAN	Kars	40° 35'	43° 4'
EAN	Iğdır	39° 55'	44° 3'
EAN	Van	38° 29'	43° 23'
EAN	Malatya	38° 21'	38° 18'
EAN	Elazığ	38° 40'	39° 13'
EAN	Bingöl	38° 53'	40° 29'
EAN	Bitlis	38° 28'	42° 9'
EAN	İspir	40° 29'	40° 59'
EAN	Tortum	40° 18'	41° 32'
EAN	Sarıkamış	40° 20'	42° 35'
EAN	Tercan	39° 46'	40° 23'
EAN	Doğubeyazıt	39° 33'	44° 5'
EAN	Arapgir	38° 2'	38° 26'
EAN	Keban	38° 47'	38° 44'

Table 2.6 : South East Anatolia region stations.

Region	Station Name	Latitude (N)	Longitude (E)
SAN	Siirt	37° 55'	41° 56'
SAN	G.Antep	37° 4'	37° 29'
SAN	Ş.Urfa	37° 9'	38° 47'
SAN	Diyarbakır	37° 54'	40° 13'
SAN	Islahiye	37° 20'	36° 38'
SAN	Kilis	36° 43'	37° 5'
SAN	Adıyaman	37° 45'	38° 16'
SAN	Ceylanpınar	36° 51'	40° 2'
SAN	Samandağ	36° 5'	35° 58'

Table 2.7 : Central Anatolia region stations.

Region	Station Name	Latitude (N)	Longitude (E)
CAN	Çankırı	40° 36'	33° 36'
CAN	Sivas	39° 45'	37° 1'
CAN	Esenboğa	39° 57'	32° 53'
CAN	Ankara	40° 4'	32° 34'
CAN	Yozgat	39° 49'	34° 48'
CAN	Kırşehir	39° 08'	34° 10'
CAN	Gemerek	39° 11'	36° 4'
CAN	Cihanbeyli	38° 39'	32° 55'
CAN	Aksaray	38° 22'	34° 0'
CAN	Nevşehir	38° 37'	34° 42'
CAN	Kayseri	38° 43'	35° 29'
CAN	Akşehir	38° 22'	31° 26'
CAN	Konya	37° 52'	32° 28'
CAN	Karaman	37° 12'	33° 13'
CAN	EreğliKonya	37° 31'	34° 2'
CAN	Niğde	37° 28'	34° 41'
CAN	Kızılcahamam	40° 28'	32° 39'
CAN	Beypazarı	40° 10'	31° 55'
CAN	Zara	39° 54'	37° 45'
CAN	Polatlı	39° 58'	32° 16'
CAN	Divriği	39° 22'	38° 7'
CAN	Ulukışla	37° 33'	37° 29'
CAN	Karapınar	37° 43'	33° 33'

Figure 2.5 showed the distribution of 134 stations over Turkey.

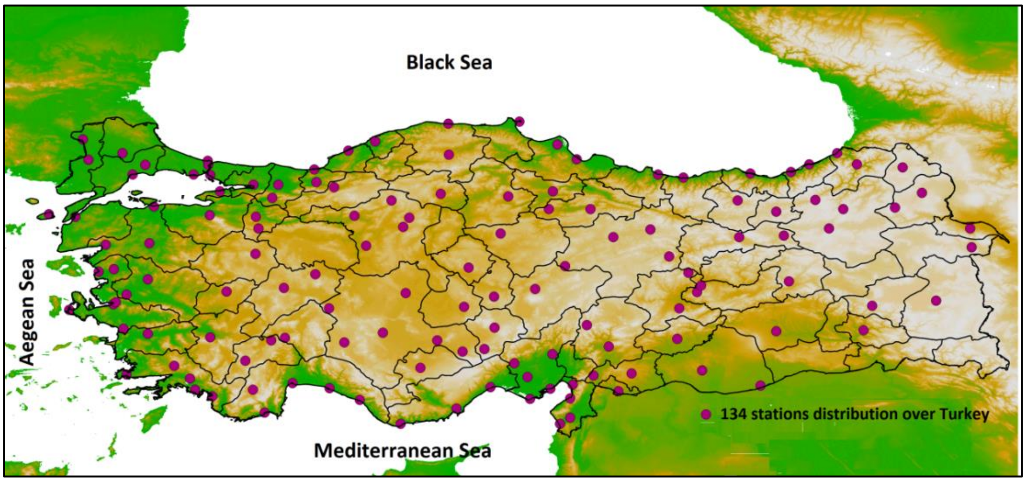

Figure 2.5 : Distribution of 134 stations over Turkey.

2.2 Methodology

Daily minimum and maximum temperature and daily precipitation data have been used for this study. At the beginning, data were arranged by using NCL software. By using this method, for some indices, daily minimum and maximum temperature data were converted to the number of days such as frost and summer. After that, in order to analyse 134 stations trends for 1965–2006 the Sequential Mann Kendall non-parametric test was applied.

This version of the Mann Kendall test used to determine beginning of a trend within a sample. The null hypothesis H0 assumes that the time series under investigation shows no beginning of a developing trend. Test statistic computed by using ranked values of the original values $(x_1,\ x_2,\ x_3,\ \ldots, x_n)$. The following steps are applied to determine trend-beginning period. Then according to this test, the null hypothesis is accepted or rejected (Gerstengarbe et al, 1999).

The test statistics variables t_i computed by the equation below

$$t_j = \sum_{1}^{j} n_j \qquad \textbf{(2.1)}$$

where n_j indicates for each element $x_j\ (j > k)$ the number of cases where $x_j > x_k$, with $j = 1, 2, ..., n$ and $k = 1, 2, ..., j-1$.

The distribution of the test statistic t_i is asymptotically normal with mean:

$$E(t_j) = [j(j-1)/4] \quad \textbf{(2.2)}$$

The variance:

$$Var(t_j) = [j(j-1)(2j+5)]/72 \quad \textbf{(2.3)}$$

Calculation of the sequential value of the test statistic $u(t)$ (progressive rows of statistic that is standardized variable or reduced variable) is given below:

$$u(t) = \frac{t_j - E(t_j)}{\sqrt{Var(t_j)}} \quad \textbf{(2.4)}$$

In order to determine the beginning of a trend retrograde row of statistics $u'(\text{t})$ is computed backwards from the end of series. When both of curves plotted then intersection of these curves, give the beginning of a developing trend within the time series. Furthermore, if $u(\text{t}) > 0$ at ± 1.96 (5% level) then it is concluded that the sample has an increasing trend. Neverthless, if $u(\text{t}) < 0$ at ± 1.96 (5% level) then it can be inferred that there is a decreasing trend in time series. Without any trend a time series plot of the values $u(\text{t})$ and $u'(\text{t})$ shows curves that overlap several times (Türkeş et al, 2002).

Figure 2.6 showed increasing trend pattern for tropical nights indices for Siirt station. Curves, $u(\text{t})$ and $u'(\text{t})$ intersect each other beyond statistically significance level around 1992 and $u(\text{t})$ indicated increasing behavior for this index from 1992 to 2006.

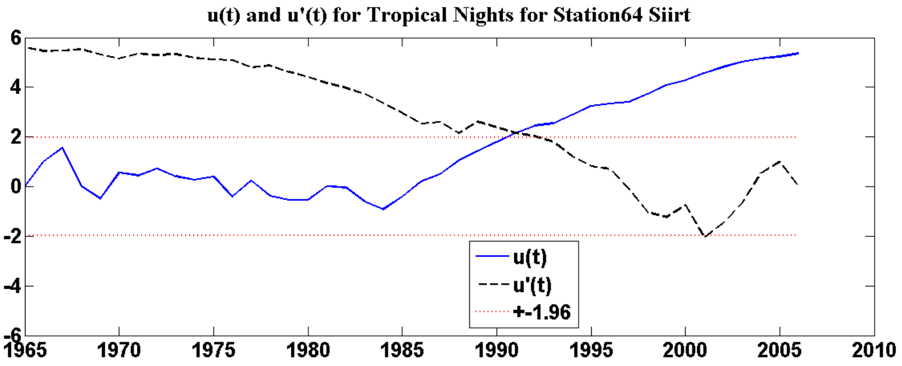

Figure 2.6 : Increasing trend pattern for tropical nights indices for Siirt station.

Figure 2.7 showed decreasing trend pattern for daily temperature range of Fethiye station for July. Curves, $u(\mathrm{t})$ and $u'(\mathrm{t})$ intersect each other around 1994 and $u(\mathrm{t})$ indicated decreasing tendency for this index from 1994 to 2006.

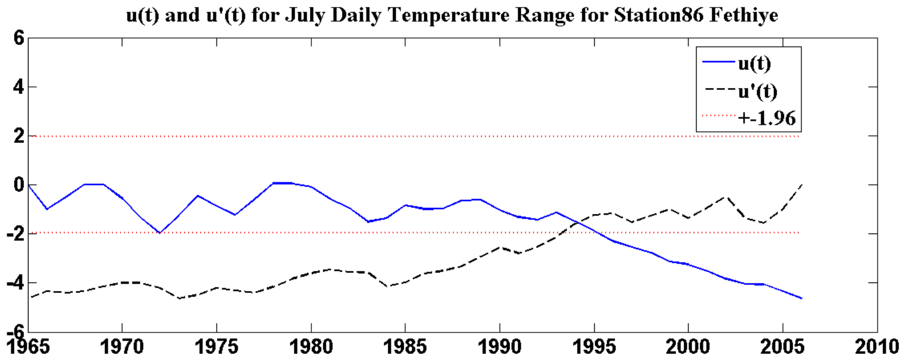

Figure 2.7 : Decreasing trend pattern for DTR indices of July for Fethiye station.

Figure 2.8 showed daily temperature range of Zonguldak station for July. For this indeces there wasn't any trend observed. Curves, $u(\mathrm{t})$ and $u'(\mathrm{t})$ intersect each other several times in the boundary of significance level.

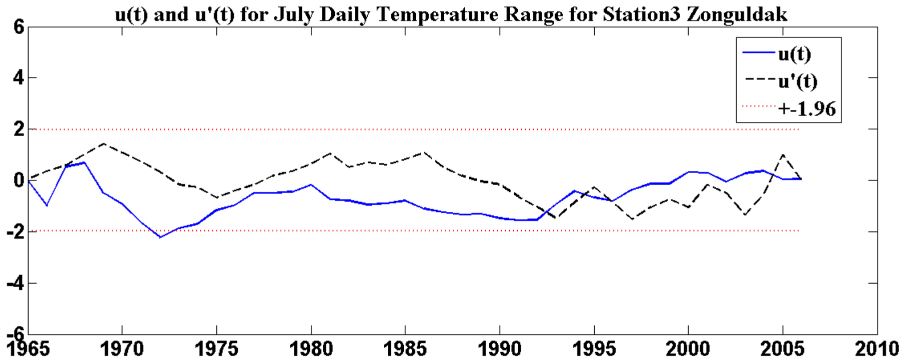

Figure 2.8 : DTR indices of July without any trend for Zonguldak station.

3. RESULTS AND DISCUSSION

Trend analysis of 134 stations with respect to 14 indices have been done by using non-parametric Sequentiall Mann Kendall Test at 5% significance level. Their results are shown below. Moreover, maximum and minimum temperatures annual trends investigation have been done for four months. They were October, May, January and July. Furthermore, their annual precipitation investigation have been done also. First of all, their results are discussed here then indices results will be explained.

3.1 Annual Maximum Temperature Trend for July

Trend analysis of annual maximum temperatures of July indicates spatially increasing trends. Stations from the west part of the country mainly located in Aegean coastal area displayed increasing trend. Besides, some stations for instance Antalya, Alanya, Silifke that located along the Mediterranean coastal areas have have an increasing tendency for annual maximum temperature of July. Furthermore, stations around Marmara Sea and Black Sea coastal areas plus most inland stations showed this behavior (Figure 3.1).

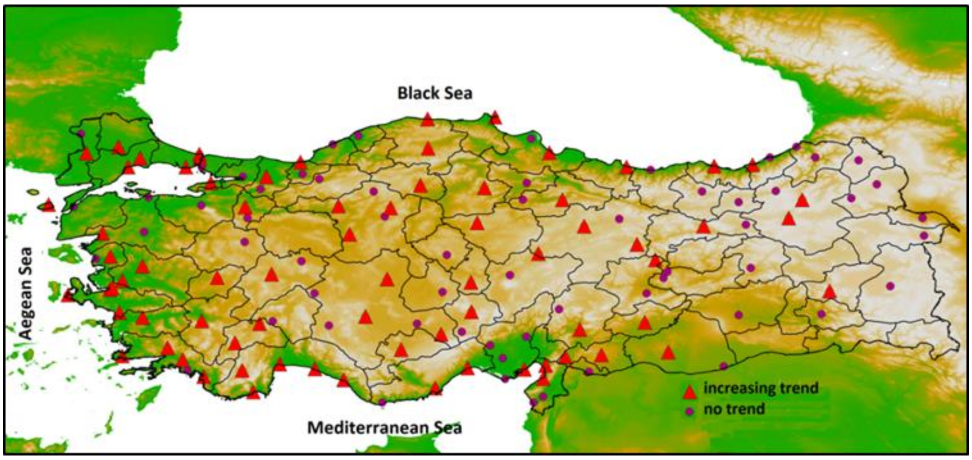

Figure 3.1 : The results of the trend for annual maximum temperature of July between 1965-2006. Statistically significant trends indicated with triangles.

3.2 Annual Maximum Temperature Trend for October

Trend analysis of annual maximum temperatures of October for the period 1965-2006 showed increasing trends for some stations. Although, there isn't any spatially coherent distribution observed throughout the country some parts indicated this tendency. Stations, for instance; Ordu, Trabzon, Rize that are located in the north-east part of the country showed this direction. Furthermore, some stations such as; Alanya, Anamur, Mersin, Yumurtalık, Tefenni in the Mediterrean and İzmir, Aydın, Denizli, Bodrum in the Aegean regions have behaviour like this. Moreover, İspir, Tortum, Doğubeyazıt, Erzurum, Kars and Arapgir stations from East Anatolia region exhibited increasing trend. In addition, from Marmara region just two stations, Yalova and Lüleburgaz displayed increasing behaviour for annual maximum temperature of October. Distribution of stations indicated in Figure 3.2.

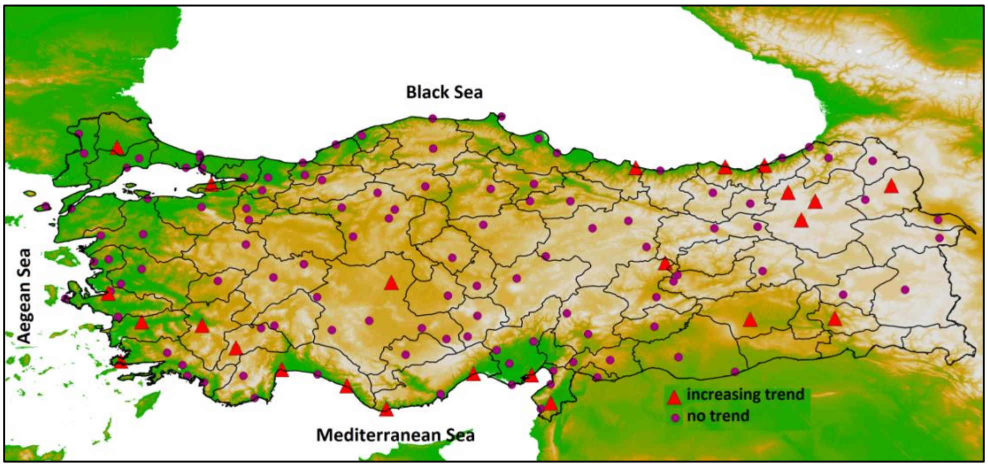

Figure 3.2 : The results of the trend for annual maximum temperature of October between 1965-2006. Statistically significant trends indicated with triangles.

3.3 Annual Maximum Temperature Trend for January

Trend analysis of annual maximum temperatures of January for 134 stations does not indicate any spatially coherent result for the period 1965-2006. However, few sitations showed increasing trends. Stations from East Anatolia region such as Kars and Van indicated this tendency. Furthermore, stations from South East Anatolia region for instance Gaziantep, and Adıyaman have behaviour like this. Moreover, stations from west part of the country for example Aydın, Bodrum, Muğla, Köyceğiz and from south part of the country such as Alanya, Antakya have displayed increasing trend. In addition, one station which is Lüleburgaz from Marmara region indicated increasing trend for annual maximum temperature of January. As a result, investigation of January annual maximum temperatures reveals increasing trend for few stations, their distribution given below (Figure 3.3).

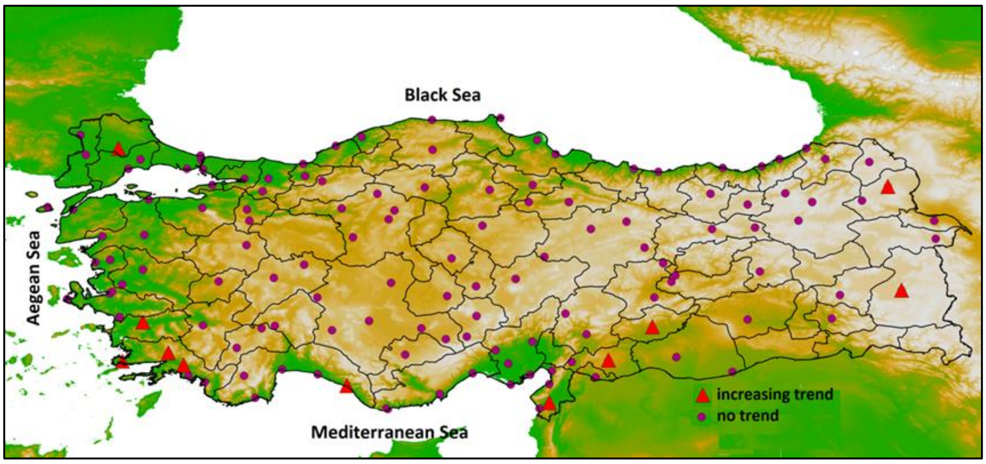

Figure 3.3 : The results of the trend for annual maximum temperature of January between 1965-2006. Statistically significant trends are indicated with triangles.

3.4 Annual Maximum Temperature Trend for May

Annual maximum temperatures of May indicated increasing trends for some stations in the west part of the country such as Aydın, Uşak Manisa. Besides, stations from the central part for example Niğde, Konya Ereğli, Polatlı showed increasing trend. Furthermore, few stations located along the Mediterrean coastal areas for instance Antalya, Antakya, Alanya, Mersin have increasing temperature tendecy also. However, one station which is Bafra showed decreasing trend for annual maximum temperature of May. Distribution of stations shown in Figure 3.4.

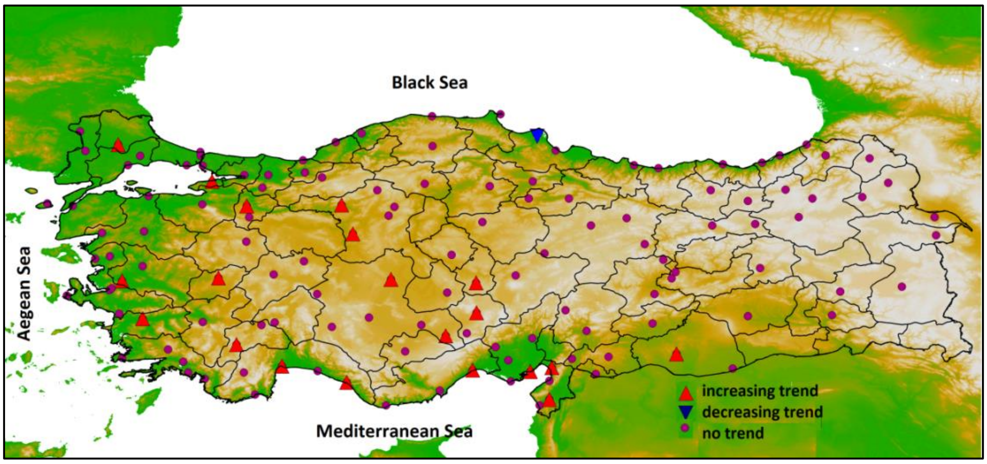

Figure 3.4 : The results of the trend for annual maximum temperature of May between 1965-2006. Statistically significant trends are indicated with triangles.

3.5 Annual Minimum Temperature Trend for July

Trend analysis of annual minimum temperatures of July indicates spatially coherent increasing trends for 93 stations. They are distributed along the three coastlines and around Marmara Sea. From the Aegean region stations (İzmir, Çeşme, Aydın, Denizli, Afyon, Kütahya) from the Mediterranean region stations (Mersin, Adana, Alanya, Anamur) and from the Black Sea region stations for example, Bartın, Sinop, Rize, Giresun have increasing trend for annual minimum temperature of July. Stations located in Marmara region such as, Bolu, Sakarya, Kocaeli, Tekirdağ have increasing tendency for annual minimum temperature of July. In addition, some inland stations such as Ankara, Konya Ereğli, Niğde, Aksaray indicated this behaviour. Furthermore, some stations located in the east part of the country for instance Van, Kars, Iğdır, Erzincan displayed increasing behaviour. However, Erzurum station indicated decreasing trend. Furthermore, some stations like Adıyaman, Kilis, Şanlıurfa from the south-east part of the country have showed increasing trend. Consequently, this analysis indicates spatially coherent increasing trends for annual minimum temperature of July. Distribution of stations shown in Figure 3.5.

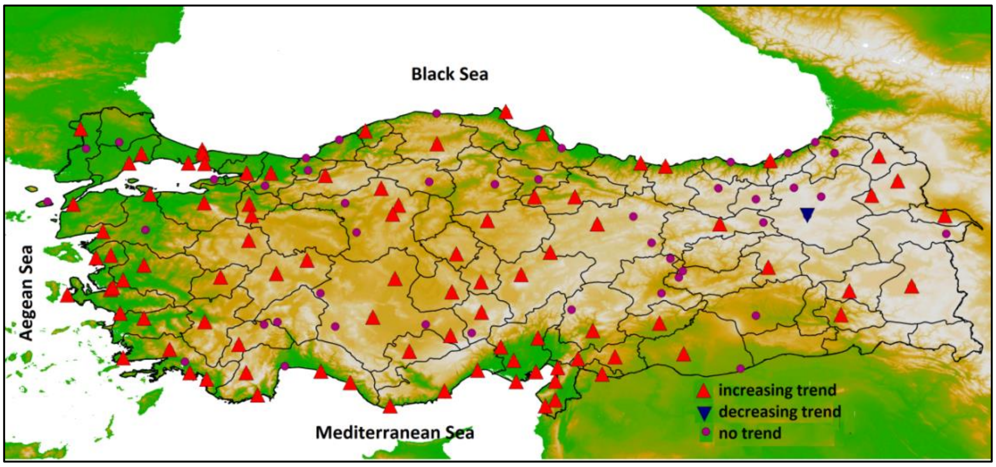

Figure 3.5 : The results of the trend for annual minimum temperature of July between 1965-2006. Statistically significant trends are indicated with triangles.

3.6 Annual Minimum Temperature Trend for October

Trend analysis of annual minimum temperatures of October for 134 stations for the period 1965-2006 reveals increasing trends for some stations. These stations located around the Marmara Sea such as Göztepe, Sakarya, Bursa, Edirne, Bolu. In addition, stations located along the Mediterrean coastal areas for example Manavgat, Antalya, Mersin, İskenderun displayed increasing trend. Furthermore, some stations from the Aegean region for instance Denizli, Akhisar indicated increasing trend for annual minimum temperature of October. Besides, some inland stations for example Ankara, Kayseri, Aksaray, Sivas showed this behaviour. In addition, stations that located in the south-east part of the country such as Gaziantep, Kilis, Kahramanmaraş, Şanlıurfa displayed the same trend for annual minimum temperature of October. Moreover, stations from the north-east part of the Black Sea region for example Ordu, Giresun, Rize have increasing tendency also. Although, few stations from the east part of the country displayed increasing trend for instance Van, Erzincan, Keban, Erzurum station indicated decreasing trend for annual minimum temperature of October. As a consequence, there was not any spatially coherent trend observed for this analysis throughout the country but mainly two coastal areas the Mediterranean and Aegen parts, north-east part of the Black Sea region, stations from the south part of the county and some inland stations displayed increasing trend. However, just one station which is Erzurum from the east part of the country showed decreasing trend. Distribution of stations given in Figure 3.6.

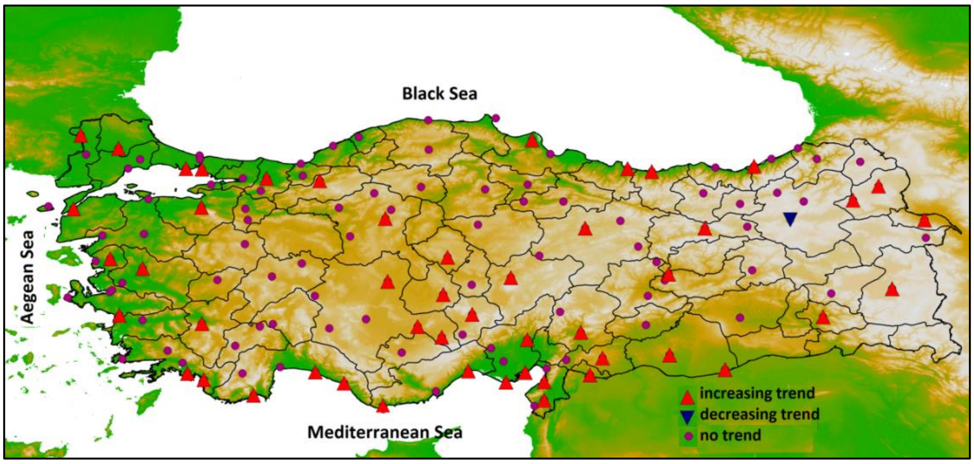

Figure 3.6 : The results of the trend for annual minimum temperature of October between 1965-2006. Statistically significant trends are indicated with triangles.

3.7 Annual Minimum Temperature Trend for May

Annual trend analysis of May minimum temperatures indicated decreasing trends for some stations in the Black Sea region but the Mediterrean and Aegean coastal areas with some inland and south-east stations, few stations on the east part of the country showed increasing trends (Figure 3.7).

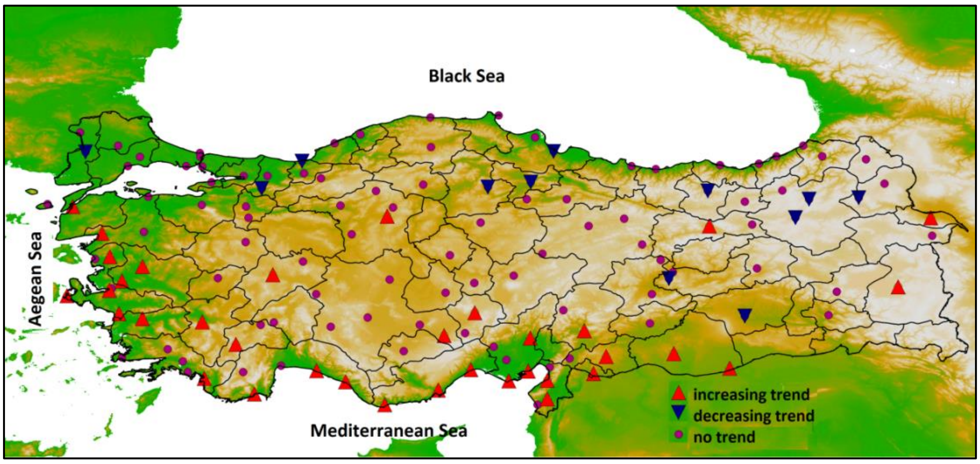

Figure 3.7 : The results of the trend for annual minimum temperature of May between 1965-2006. Statistically significant trends are indicated with triangles.

3.8 Annual Precipitation Trends for Four Months

Annual trend analysis of precipitation for four months (October, May, July, January) does not show any trends. There wasn't any precipitation patterns found.

3.9 Number of Frost Days Trend Analysis

FD, Number of frost days mean: Annual count of days when TN- daily minimum temperature is less than 0°C. Analysis of this indices revealed that there is no spatially coherent increasing or decreasing trend throughout the country. However, few stations that indicate increase in frost days number are mainly in the northern half of the country plus few inland stations (Figure 3.8).

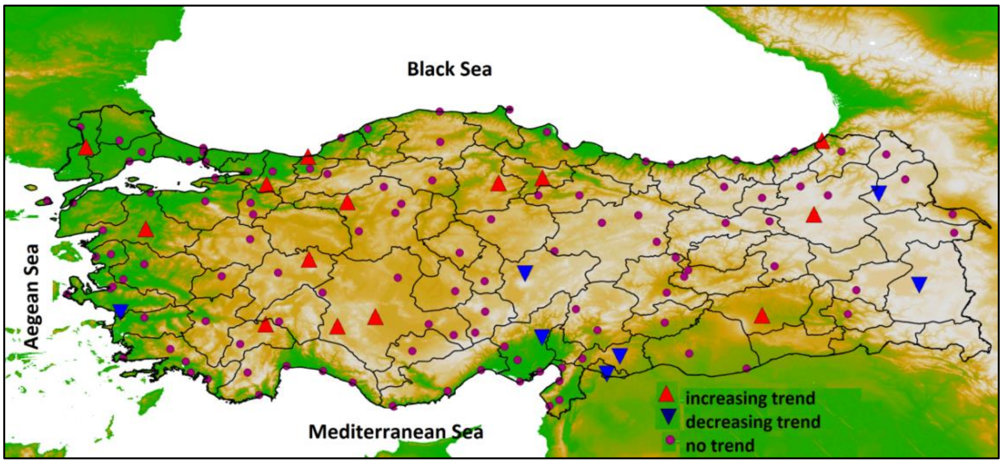

Figure 3.8 : Distribution of frost days stations.Statistically significant trend indicated with triangles

3.10 Number of Summer Days Trend Analysis

Number of summer days, SU refers to annual count of days when TX- daily maximum temperature is greater than 25°C. Summer days are increasing in Turkey. The significant increases distributed throughout the country with the exception of southeastern Anatolia region (Figure 3.9).

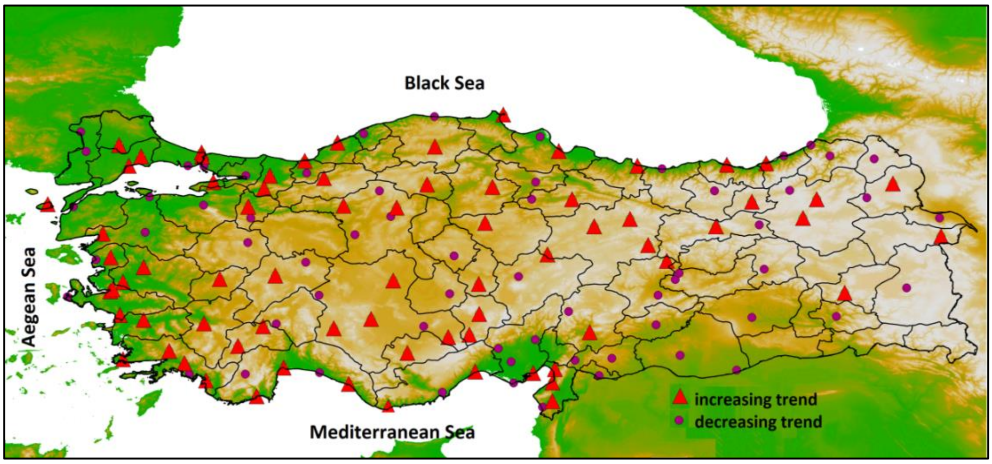

Figure 3.9 : Distribution of summer days stations. Statistically significant trends indicated with triangles.

3.11 Number of Tropical Nights Trend Analysis

Number of tropical nights, TR refers to annual count of days when TN- daily minimum temperature is greater than 20°C. Investigation of this indices indicated that stations located on northeast of the country and coastal regions around the Marmara Sea and the Mediterranean showed increasing trend (Figure 3.10).

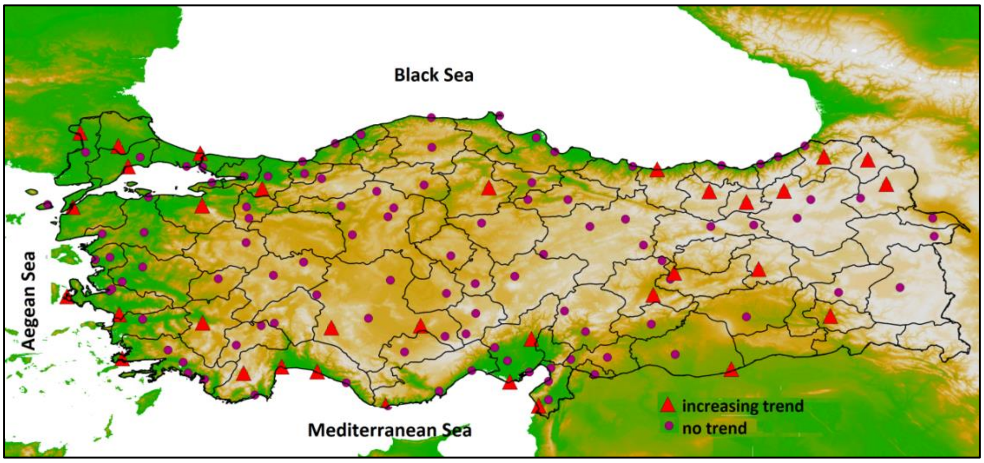

Figure 3.10 : Distribution of tropical nights stations. Statistically significant trends indicated with triangles.

3.12 Monthly Maximum Value of Daily Minimum Temperature for July

Trend analysis of monthly maximum value of daily minimum temperature of July showed increasing trends along coastal areas especially Aegean and the Mediterrean. Besides, some stations around Marmara Sea exhibited this behaviour. Furthermore, few stations on the Black Sea coastline and some inland stations indicated this trend also (Figure 3.11).

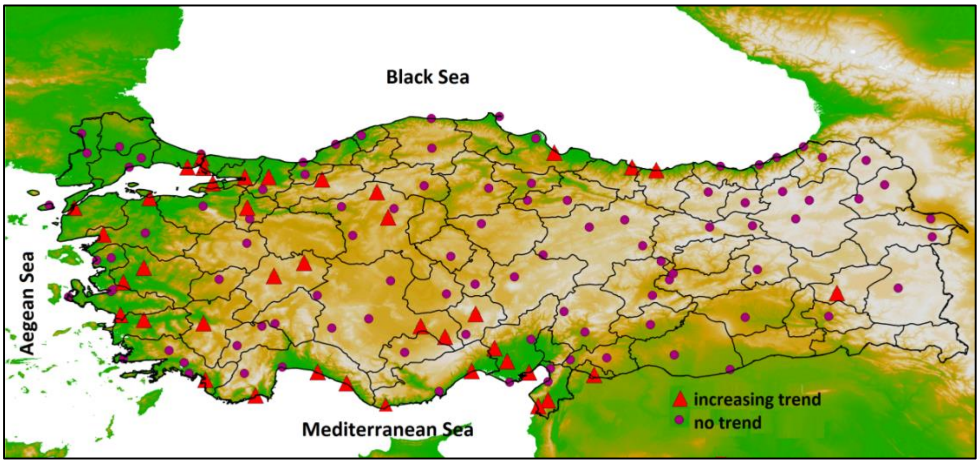

Figure 3.11 : Stations for monthly maximum value of daily minimum temperature of July. Statistically significant trends shown in triangles.

3.13 Monthly Minimum Value of Daily Maximum Temperature for July

Monthly minimum value of daily maximum temperature analysis for July months indicated increasing trends among stations located especially along Aegean and the Mediterrean coastal areas. In addition, some stations on the Southeast, Central Anatolia and northeast of the Black Sea Region revealed increasing trends (Figure 3.12).

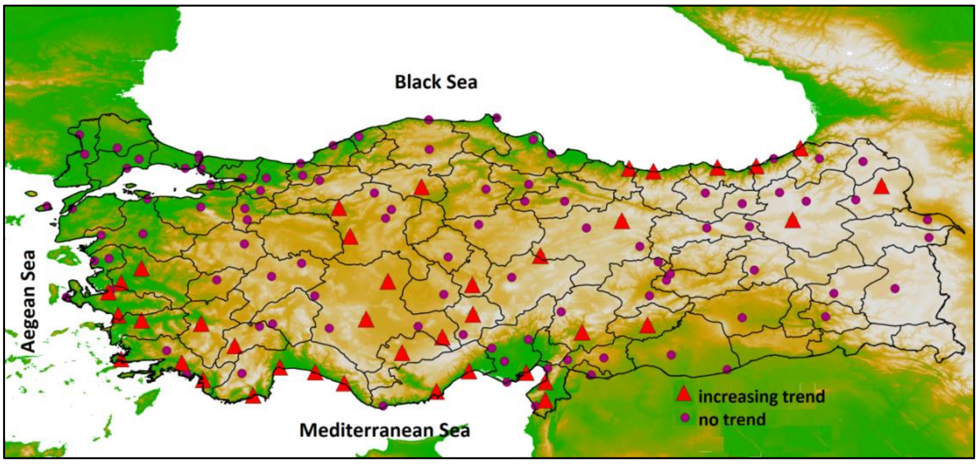

Figure 3.12 : Stations distribution for monthly minimum value of daily maximum temperature of July. Statistically significant trends shown in triangles.

3.14 Monthly Minimum Value of Daily MinimumTemperature for July

Monthly minimum value of daily minimum temperature analysis for July months indicated increasing trends along the Mediterranean, Aegean coastlines and some stations around Marmara Sea. Moreover, some stations on the west, central and northern part of the country behave in the same manner (Figure 3.13).

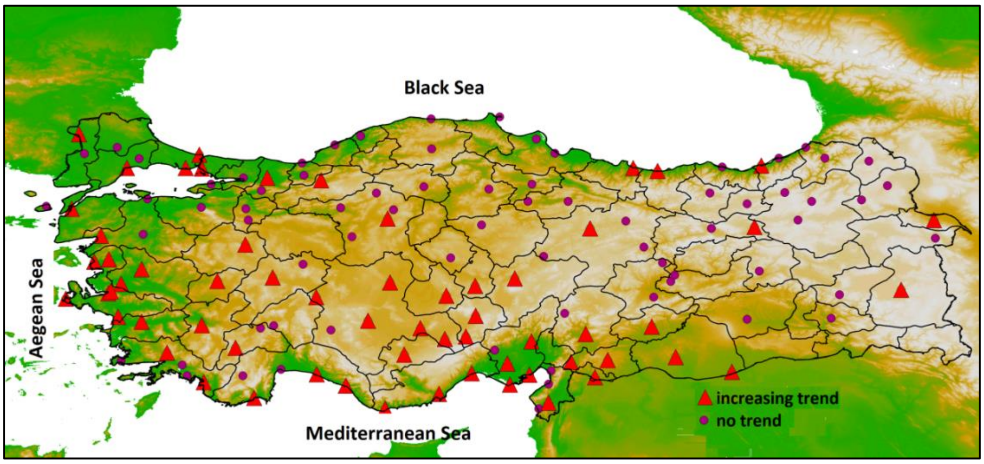

Figure 3.13 : Stations for monthly minimum value of daily minimum temperature for July. Statistically significant trends are shown by triangles.

3.15 Daily Temperature Range for January

Daily temperature range (DTR) refers to the monthly mean difference between maximum and minimum temperature of a day. DTR trend analysis has been done for January and July. There weren't any spatially coherent trends found for January. Some stations showed decreasing, some Aegean coastline and inland stations showed increasing trend. Distribution of the stations are shown in Figure 3.14.

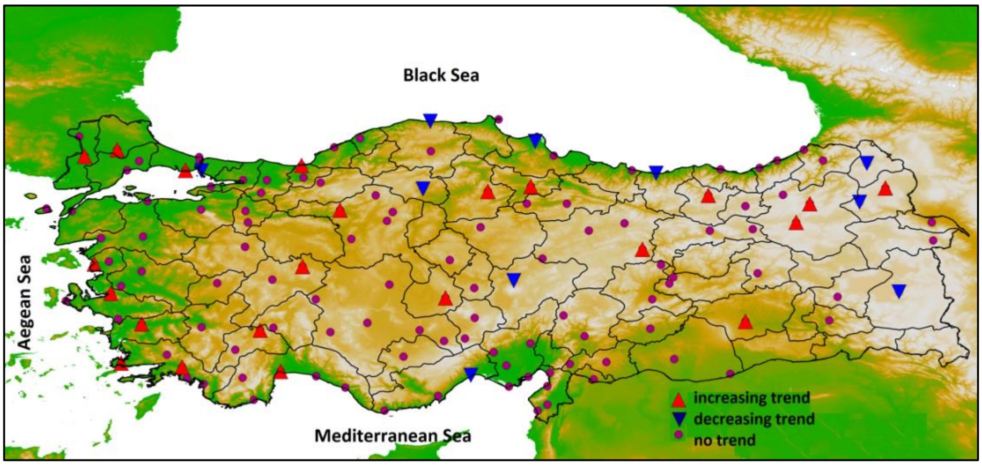

Figure 3.14 : Distribution of stations for daily temperature range for January.

3.16 Daily Temperature Range for July

Stations located on the northern part of the country showed increasing trend for DTR of July. However, there was decreasing trend among the stations located on the Mediterranean coastal areas and southeast and east part of the country. Distribution of the stations are shown in Figure 3.15.

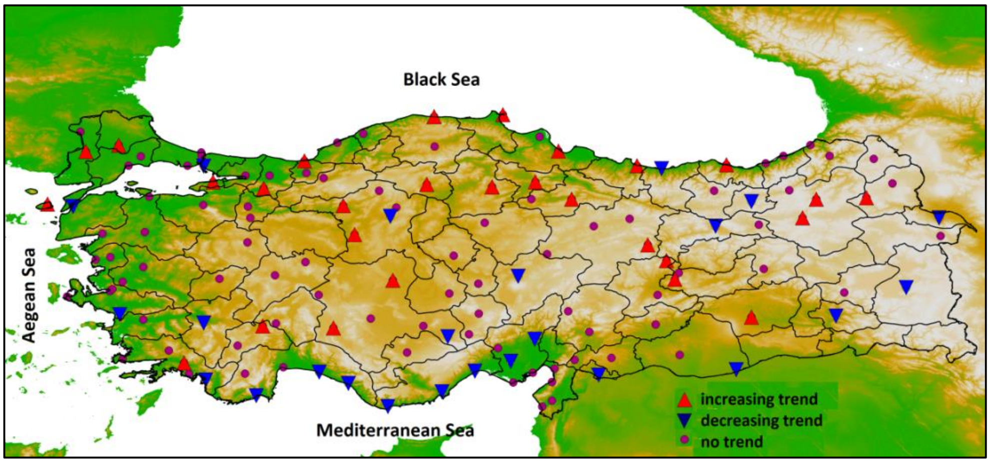

Figure 3.15 : Distribution of stations for daily temperature range for July.

3.17 Numbers of Icing Days

Icing days, ID refer to annual count of days when TX, daily maximum temperature is less than 0°C. There wasn't any trend observed for icing days.

3.18 Growing Season Length

Growing season length, GSL refers to annual (1st Jan to 31 Dec in Northern Hemisiphere) count between first span of at least 6 days with daily mean temperature TG >5°C and first span after July 1st of 6 days with TG <5°C. There wasn't any trend observed for this indis between the period 1965 – 2006. Stations on the coastal regions may have growing season length exceding 365 days. For example Samandağ station daily mean temperature does not fall below 5°C in 1965, 1980, 2000.

3.19 Precipitation Indices

Precipitation indices; Rx1day that is monthly maximum 1-day precipitation, Rx5day monthly consecutive 5-day precipitation have been investigated but there weren't any trends observed for them. Moreover, annual count of days when precipitation greater than 10 mm and 20 mm were analysed but there were not any trend found for them also.

3.20 General Assesment

General assessment between the stations and indices give us some consequences. These results are obtained from comparing the tables that given in appendix of this study. The information obtained from the tables is

- Two stations from Black Sea region and six stations from Mediterranean region have the same tendency for monthly minimum of daily maximum (TXn), monthly minimum of daily minimum (TNn) and monthly maximum of daily minimum (Tnx) indices for July months. All of them are increasing.
- Four stations from Aegean region showed increasing trends for monthly minimum of daily maximum (TXn), monthly minimum of daily minimum (TNn) and monthly maximum of daily minimum (Tnx) indices for July

months. Besides, for these stations daily maximum temperatures are greater than 25 °C. As a result their summer days increased also.

- Seven stations from Central Anatolia region, three stations from South East Anatolia region and three stations from Marmara region indicated increasing trends for monthly minimum of daily maximum (TXn), monthly minimum of daily minimum (TNn) indices for July.
- Four stations, Tekirdağ, Kumköy, Lüleburgaz and Geyve from Marmara region have daily maximum temperatures greater than 25 °C that their summer days increased. In addition, their daily minimum temperatures grater than 20 °C which means their tropical nights increased also.
- Two stations, Çorum and Bayburt from Black Sea region, two stations, Antalya and Anamur from Mediterranean region, three stations, Denizli, Bodrum, Selçuk from Aegean region, one station, Kars, from East Anatolia region and four stations Tekirdağ, Kumköy, Lüleburgaz and Geyve from Marmara region have daily maximum temperatures greater than 25 °C. Hence, in those stations summer days increased. Moreover, their daily minimum temperatures are grater than 20 °C which means their tropical nights increased also.

4. CONCLUSIONS AND RECOMMENDATIONS

This study aims to analyse 134 stations extreme temperature and precipitation indices trends for the period 1965 -2006. Daily temperature and precipitation data used for this analysis was obtained from Turkish State Meteorological Service. The stations were chosen by data visualization methods to eliminate missing value stations.

Fourteen climate indices have been investigated for their trends. Furthermore, annual maximum and minimum temperature and precipitation trends have been done for October, May, January and July.

4.1 Annual temperature and precipitation trends results

- Annual maximum temperatures of July showed spatially increasing trends for coastline and most inland stations and stations around Marmara Sea.
- Annual maximum temperatures of October indicated increasing trends for north-east part of the country. Moreover, some stations on the Mediterrean and Aegean coastal areas have a tendency like this.
- Investigation of annual maximum temperatures of January does not indicate any spatially coherent trend.
- Trend analysis of May annual maximum temperatures showed that stations located on west and central part of the country with few stations along the Mediterrean coastal areas have increasing trends. In contrast, one station which is Bafra showed decreasing trend.
- Annual minimum temperatures of July showed that spatially coherent increasing trends for 93 stations. They distributed along the coastlines, inland, east and south-east part of the country. However, Erzurum station indicated decreasing trend.
- Trend analysis of October annual minimum temperatures revealed that stations around the Marmara Sea, along the Mediterrean and Aegean coastal areas with some inland and south-east stations, the north-east part of the

Black Sea region and few stations on the east part of the country showed increasing trends. However, Erzurum station indicated decreasing trend.

- Annual minimum temperatures of May indicated decreasing trends for some stations in the Black Sea region. By contrast, stations on the Mediterrean and Aegean coastal areas with some inland and south-east stations, few stations on the east part of the country showed increasing trends.
- Annual trend analysis of precipitation for four months does not show any trends. There were not any precipitation patterns found.

4.2 Indices trends results

- Number of summer days and tropical nights has increased significantly whereas there was not any spatially coherent trend observed for frost days.
- The statistical analysis indicated that monthly minimum value of daily maximum temperature of July have an increasing trend for stations located especially in Aegean and the Mediterranean coastal areas. In addition, some stations from the Southeast, Central Anatolia and northeast of the Black Sea region have displayed increasing trend.
- Trend analysis of monthly minimum value of daily minimum temperature for July indicated increasing trends along the Mediterranean, Aegean coastlines and some stations around Marmara Sea. Moreover, some stations on the west, central and northern part of the country behave in the same manner.
- Daily temperature range trend analysis has been done for January and July. There weren't any spatially coherent trends found for January. Some stations showed decreasing, some Aegean coastline and inland stations showed increasing trend.
- Trend analysis of July months indicated that stations located on the northern part of the country showed increasing trend whereas there was a decreasing trend among the stations located on the Mediterranean coastal areas and southeast and east part of the country.
- There weren't any trends observed for icing days.
- There weren't any trends observed for growing season length indices.

- There weren’t any trends observed for precipitation indices, Rx1day, Rx5day, R10mm and R20mm.

4.3 Discussions

As it is known that climate extremes has significant affects on nature, society and economy. Some important areas that are affected by extremes are ecosystems, forestry, agriculture, water resources, tourism, health and insurance and energy sectors (Kostopoulou et al, 2005). Extreme weather can have significant effects on wild life populations and its dynamics. Many population extinctions occurred due to this reason, for example Edith’s Checkerspot butterfly (Parmesan et al, 2000). Distribution of species, their morphology, behavior and population influenced by extreme events (Easterling et al, 2000). Increase in droughts, flooding events, heat stress have an important impacts on crop yields and livestock productivity, both of them are reduced. Besides, extremes have negative consequences on food, fibre and forestry (IPCC, 2007). Changes in extremes intensity and frequency have significant impacts on health. Both low-income and high-income countries affected by these extremes. For example, at 2003 heat wave affects Europe. Occurrence of deaths increased by 140 % in Paris (Haines et al, 2005). Damages due to extreme events such as floods, storms and droughts affects insurance industry. Moreoever, tourism and energy sectors also influenced by extremes.

Therefore, to study the trend in climate extreme events became crucial due to damaging effects on human comfort. According to the fourth assessment report of Interngovernmental Panel on Climate Change (IPCC, 2007) Turkey and the Meditarranean Basin are one of the most vulnerable region to climate change. To understand the future change in climate extremes, we first have to investigate the past trend in climate extremes in Turkey.

Hence, in this study, we have examined 14 climate extreme indices which emphasizing changes in temperature and precipitation extremes for 134 stations for the period 1965-2006 for Turkey. The results shows statistically significant increasing trends for temperature data. Tropical nights and summer days have been increased all over Turkey. Monthly minimum and maximum temperatures reveals increasing trend for July throughout the country. Daily temperature range of July exhibits decreasing trend mainly in the south coastline and south part of the country. There wasn’t any trend observed for precipitation pattern. In general, there was an increasing trend observed for minimum and maximum temperature throughout the country especially warmer parts of the year. Hence, in Turkey we may have experiences like given examples due to climate extremes effects.

In this study, possible errors occurred due to data itself because we haven’t got any metadata and we didn’t do any homogeneity test. Equipments and their positions in the stations may changed. However, we didn’t pay attention to singular changes we focused on coherency.

REFERENCES

Ahrens, C. D. (2007). The Earth's Atmosphere. In essentials of meteorology, An Invitation to The Atmosphere (5th edition pp. 13). Belmont, Brooks/Cole.

Easterling, D. R. (2000). Climate extremes, observations, modeling and impacts. *Science*, **289**, 2068 doi: 10.1126/science.289.5487.2068.

Gerstengarbe, F. P., Werner. C. 1999: Estimation of the beginning and end of recurrent within a climate regime. *Climate Research*, **11**, 97-107.

Haines, A., Kovats, R. S., Lendrum, D. C., Corvalan, C. (2006). Climate change and human health, impacts, vulnerability and public health, *Public Health,* **120**, 585-596.

Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, X.D., Maskell, K. et al. (2001). Climate Change 2001. *The scientific basis contribution of working groups I, II and III to the thirth assessment report of Intergovernmental Panel on Climate Change*. Cambridge University Press, United Kingdom, 881 pp.

Houghton, J. T. (2004). The Greenhouse Effect. In global warming (3th edition, pp.15) United Kingdom, Cambridge University Press.

Kahya, E., and Partal, T. (2005). Trend analysis in Turkish precipitation data, *Hydrolog Process*. **20**, 2011-2026.

Kump, L. R., Kasting, J. F., Crane, R.G. (2004). Global Energy Balance: The Greenhouse Effect. In the earth system (2nd edition, pp.44) New Jersey, Pearson Prentice Hall.

Kostopoulou, E., Jones, P. D. (2005). Assessment of climate extremes in the Eastern Mediterranean, *Meteorol Atmos Phys.*, **89**, 69-85

Lutgens, F. K., Tarbuck, E. J., Tasa, D. (2010). Global Climate Change. In essentials of geology (11th edition, pp.505) New Jersey, Pearson Prentice Hall.

Parmesan. C., Root T. L., Willig M. R. (2000). Impacts of extreme weather and climate on terrestrial biota, *Bull. Amer. Meteor. Soc.*, **81**, 443-450.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hansen, C.E., (2007). Climate Change 2007 impacts, adaptation and vulnerability. *Contribution of working groups I, II and III to the fourth assessment report of Intergovernmental Panel on Climate Change.* Cambridge University Press, United Kingdom, 275 pp.

Rajendra, K. P., Reisinger, A., Geneva. (2007). Climate Change 2007. *Synthesis report contribution of working groups I, II and III to the fourth assessment report of Intergovernmental Panel on Climate Change.* Genava, Switzerland, 104 pp.

Şen, Ö. L. (2013). A holistic view of climate change and its impacts in Turkey, IPC report, Istanbul, Turkey.

Şensoy, S., Demircan, M., and Alan, İ. (2005). 1971 2004 yılları arası Türkiye iklim indisleri trendleri, Devlet Meteoroloji İşleri Genel Müdürlüğü, Ankara, Türkiye.

Şensoy, S., Demircan, M., Ulupınar, Y., & Balta, İ. (2008). Climate of Turkey, Department of research, Turkish State Meteorological Service, Ankara, Turkey.

Taylor, F. W. (2005). The Climate System. In elementary climate physics (1th edition, pp.1) Newyork, Oxford Universtiy Press.

Türkeş, M., Sümer, U. M., Demir, İ. (2002). Re-evaluation of trends and changes in mean, maximum and minimum temperatures of Turkey for the period 1929-1999, *Int J Climatol*., **22**, 947-977.

Türkeş, M., Sümer, U. M., Demir, İ. (2004). Spatial and temporal patterns of trends and variability in diurnal temperature range of Turkey, Department of research, Turkish State Meteorological Service, Ankara, Turkey.

Url-1 <*http://etccdi.pacificclimate.org*>, date retrieved 17.11.2013

Zhang, X., Aguilar, E., Şensoy, S., Melkonyan, H., Tagiyeva, U., Ahmed, N. et al**.** (2005). Trends in Middle East climate extreme indices from 1950 to 2003. *Journal of Geophysical Research, 110,* 2005.

APPENDICES

APPENDIX A

1. FD, Number of frost days: Annual count of days when TN- daily minimum temperature < 0°C.

   Let TN_{ij} be daily minimum temperature on day i and year j. Count the number of days where $TN_{ij} < 0$ °C.

2. SU, Number of summer days: Annual count of days when TX- daily maximum temperature > 25°C.

   Let TX_{ij} be daily maximum temperature on day i and year j. Count the number of days where $TX_{ij} > 25$ °C.

3. ID, Number of icing days: Annual count of days when TX- daily maximum temperature < 0°C.

   Let TX_{ij} be daily maximum temperature on day i and year j. Count the number of days where $TX_{ij} < 0$ °C.

4. TR, Number of tropical nights: Annual count of days when TN- daily minimum temperature > 20°C.

   Let TN_{ij} be daily minimum temperature on day i and year j. Count the number of days where $TN_{ij} > 20$ °C.

5. GSL, Growing season length: Annual (1st Jan to 31st Dec in Northern Hemisphere), count between first span of at least 6 days with daily mean temperature TG>5°C and first span after July of 6 days with daily mean temperature TG<5°C.

   Let TG_{ij} be daily mean temperature on day i and year j. Count the number of days between the first occurrence of at least 6 consecuitive days with TG_{ij} > 5°C and the first occurrence after 1st July of at least 6 consecuitive days with $TG_{ij} <$ 5°C.

6. TXx, Monthly maximum value of daily maximum temperature:

   Let TXx be daily maximum temperatures in month k, period j. The maximum daily maximum temperature each month is then $TX_{xkj} = \max(TX_{xkj})$

7. TNx, Monthly maximum value of daily minimum temperature:

   Let TNx be daily minimum temperatures in month k, period j. The maximum daily minimum temperature each month is then $TN_{xkj} = \max(TN_{xkj})$

8. TXn, Monthly minimum value of daily maximum temperature:

   Let TXn be daily maximum temperatures in month k, period j. The minimum daily maximum temperature each month is then $TX_{nkj} = \min(TX_{nkj})$

9. TNn, Monthly minimum value of daily minimum temperature:

   Let TNn be daily minimum temperatures in month k, period j. The minimum daily minimum temperature each month is then $TN_{nkj} = \min(TN_{nkj})$

10. DTR, Daily temperature range: Monthly mean difference between TX and TN

    Let TX_{ij} and TN_{ij} be the daily maximum and minimum temperature respectively on day i and period j. If I represent the number of days in j, then: $DTR_j = \frac{\sum(Tx_{ij} - Tn_{ij})}{I}$

11. Rx1day, Monthly maximum 1- day precipitation:

    Let RR_{ij} be daily precipitation amount on day i and period j. The maximum 1-day values for period j are: Rx1dayj= $\max RR_{ij}$

12. Rx5day, Monthly maximum consecutive 5-day precipitation:

    Let RR_{kj} be the precipitation amount for the 5-day interval ending k, period j. Then maximum 5-day values for period j are: Rx5dayj= $\max RR_{kj}$

13. R10mm, Annual count of days when PRCP≥10mm:

    Let RR_{ij} be daily precipitation amount on day i and period j. Count the number of days where $RR_{ij} \geq$10mm.

14. R10mm, Annual count of days when PRCP≥20mm:

    Let RR_{ij} be daily precipitation amount on day i and period j. Count the number of days where $RR_{ij} \geq$20mm.

APPENDIX B

Table B.1 : Indices definitions and its abbrevations.

Indices	Definitions
FD	Number of frost days
ID	Number of icing days
SU	Number of summer days
TR	Number of tropical nights
TXx	Monthly maximum value of daily maximum temperature
TNx	Monthly maximum value of daily minimum temperature
TXn	Monthly minimum value of daily maximum temperature
TNn	Monthly minimum value of daily minimum temperature
DTR	Daily temperature range for

Table B.2 : Indices distribution for Black Sea region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Akçakoca	inc	dec	inc						inc	inc
Bartın										
Zonguldak			inc							
İnebolu			inc						dec	inc
Sinop			inc							inc
Samsun			inc			inc				inc
Ordu			inc			inc	inc	inc		inc
Giresun				inc		inc	inc	inc	dec	dec
Rize			inc				inc			
Trabzon			inc				inc			inc
Hopa	inc						inc			
Artvin				inc						
Kastamonu			inc							
Çorum	inc		inc	inc					inc	inc
Amasya									inc	inc
Tokat			inc							inc
Gümüşhane				inc					inc	
Bayburt			inc	inc						dec
Bafra									dec	
Pazar-Rize										
Düzce										
Zile								inc		

Table B.3 : Indices distribution for Mediterranean region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Isparta										
Beyşehir	inc		inc	inc						inc
K.Maraş			inc				inc	inc		
Antalya			inc	inc			inc		inc	
Alanya			inc			inc	inc	inc		dec
Anamur			inc	inc		inc		inc		dec
Silifke							inc	inc		dec
Mersin			inc			inc	inc	inc	dec	dec
Adana						inc		inc		dec
İskenderun			inc				inc			
Antakya			inc			inc	inc	inc		
Finike			inc			inc	inc	inc		dec
Göksun										
Tefenni			inc				inc	inc		
Kozan				inc				inc		dec
Karaisalı						inc				
Elmalı				inc						
Manavgat				inc		inc	inc	inc		dec
Dörtyol			inc							
Yumurtalık			inc			inc	inc	inc		
Karataş				inc				inc		

Table B.4 : Indices distribution for Aegean region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Kütahya								inc		
Dikili								inc	inc	
Akhisar			inc			inc	inc	inc		
Manisa			inc			inc	inc	inc		
Uşak			inc					inc		
Afyon			inc			inc		inc		
İzmir			inc				inc	inc		
Çeşme				inc				inc		
Aydın			inc			inc	inc	inc	inc	
Denizli			inc	inc		inc	inc	inc		dec
Burdur	inc		inc						inc	inc
Bodrum			inc	inc			inc		inc	
Muğla			inc					inc		
Dalaman										
Fethiye			inc			inc	inc	inc		dec
Bergama			inc					inc		
Bornova			inc					inc	inc	
Selçuk			inc	inc		inc	inc	inc		dec
Köyceğiz			inc				inc		inc	inc
Emirdağ	inc					inc			inc	

Table B.5 : Indices distribution for Central Anatolia region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Çankırı			inc						dec	inc
Sivas			inc				inc	inc		
Esenboğa			inc							
Ankara						inc		inc		dec
Yozgat			inc							
Kırşehir										
Gemerek			inc				inc			
Cihanbeyli			inc				inc	inc		inc
Aksaray								inc		dec
Nevşehir			inc				inc	inc	inc	
Kayseri	dec							inc	dec	dec
Akşehir								inc		
Konya	inc		inc				inc	inc		
Karaman			inc				inc	inc		
EreğliKonya			inc			inc	inc	inc		dec
Niğde			inc			inc	inc	inc		
Kızılcahamam						inc				
Beypazarı	inc		inc				inc		inc	inc
Zara			inc				inc			
Polatlı							inc			inc
Divriği			inc						inc	inc
Ulukışla			inc					inc		
Karapınar				inc		inc		inc		

Table B.6 : Indices distribution for East Anatolia region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Ardahan				inc					dec	
Erzincan			inc			inc	inc	inc		dec
Erzurum	inc		inc					dec	inc	inc
Kars		dec	inc	inc			inc		inc	
Iğdır								inc		dec
Van	dec	dec						inc	dec	dec
Malatya				inc						
Elazığ										inc
Bingöl				inc						
Bitlis			inc			inc	inc			
İspir				inc						
Tortum			inc						inc	inc
Sarıkamış	dec							inc	dec	dec
Tercan										
Doğubeyazıt			inc							
Arapgir			inc	dec						inc
Keban				inc						

Table B.7 : Indices distribution for South East Anatolia region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Siirt				inc						dec
G.Antep	dec						inc	inc		
Ş.Urfa						inc	inc	inc		
Diyarbakır							inc		inc	inc
Islahiye							inc	inc		
Kilis						inc		inc		dec
Adıyaman							inc	inc		
Ceylanpınar				inc				inc		dec
Samandağ				inc		inc				

Table B.8 : Indices distribution for Marmara region.

Stations	FD	ID	SU	TR	TXx	TNx-July	TXn-July	TNn-July	DTR-Jan	DTR-July
Edirne				inc				inc		
Çorlu			inc							
Tekirdağ			inc	inc				inc		
Kumköy			inc	inc			inc	inc		
Kireçburnu			inc			inc				
Göztepe						inc		inc	dec	dec
Kocaeli						inc				
Sakarya			inc			inc	inc	inc		
Bolu			inc			inc	inc	inc		
Gökçeada			inc							inc
Çanakkale				inc		inc		inc		dec
Bandırma						inc				
Bursa				inc						
Yalova			inc			inc	inc			inc
Bilecik			inc			inc				
Edremit			inc			inc	inc	inc		
Balıkesir	inc									
Uzunköprü	inc								inc	inc
Lüleburgaz			inc	inc			inc		inc	inc
Florya						inc		inc	inc	
Geyve	inc		inc	inc						inc
Bozüyük										

CURRICULUM VITAE

Name Surname: Berna Dündar

Place and Date of Birth:

Address:

E-Mail:

B.Sc.: Middle East Technical University, Physics Department

M.Sc.:

Professional Experience and Rewards:

List of Publications and Patents:

PUBLICATIONS/PRESENTATIONS ON THE THESIS

- **Dundar**, **B**., Göktürk, O.M., Sen, O.L., 2014. Trend analysis of frost days and summer days data in Turkey for the period 1965-2006. Climate change and climate dynamics international conference. 8-10 October 2014, Istanbul-Turkey.