TRENDS IN TURKEY CLIMATE INDICES FROM 1960 TO 2010

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Abstract
Extreme climate events usually have strong impacts on society, water resources, health, and agriculture sectors. Small change in the mean condition can cause a large change in the likelihood of an extreme. In this study we have run RClimDex software in order to calculate climate indices for 109 stations in Turkey for the period from 1960 to 2010.
The results show that numbers of summer days, warm days, warm nights and tropical nights have been increasing all over Turkey while frost days, cool days and cool nights are decreasing. Most of the trends are statistically significant at the 95% level. Growing season length has increased over Turkey except coastal regions.
Trend in annual total precipitation is increasing in northern parts of the country while decreasing in Southeastern Anatolia, Mediterranean and Aegean Regions. Numbers of heavy precipitation days have been increasing in most of the stations except Aegean and Southeastern Anatolia and usually cause extreme flood events. The maximum 1-day precipitation has been increasing in most of the stations except Southeastern Anatolia.

Keywords: *RClimDex, climate, extreme, indices, trend*

Introduction

Climate change is one of the biggest issues confronting humanity in the 21st century. This will give rise to changes in weather patterns, and an increase in the frequency and severity of extreme events. Given the complexity and global nature of the climate system, cooperative activities within international and interdisciplinary programs are indispensable for monitoring and predicting climate change. A joint WMO CCl/CLIVAR Expert Team (ET) on Climate Change Detection, Monitoring and Indices has defined 27 core climate indices mainly focusing on extreme events using freely available software, RClimDex produced on behalf of the ET by Xuebin Zhang from Environment Canada and running under free “R” statistical package.

Materials and methods

In this study, we have run RClimDex software to calculate climate extreme indices for about 109 stations in Turkey for the period from 1960 to 2010. We selected the same data period in order to compare station’s outputs for the same climatic period. To provide an overall picture of climate variation in the country, we computed average trends for every index, relative to the period 1971-2000. Before the index calculation, data quality controlled and their homogeneity tested. RClimDex software and users guide are available from

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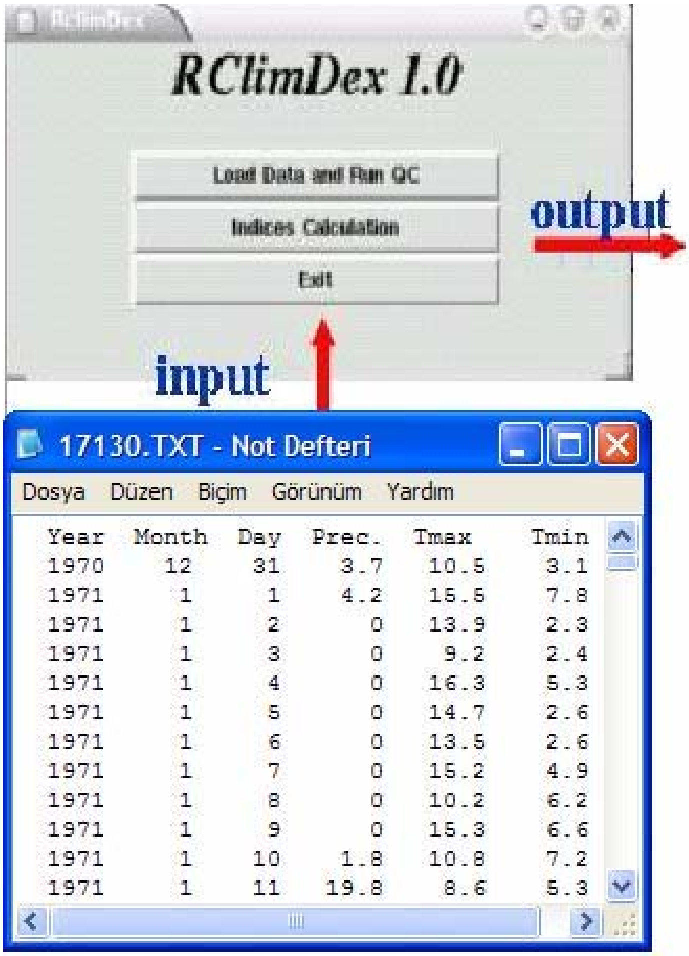

Figure 1. Software and raw data
http://cccma.seos.uvic.ca/ETCCDMI.

Quality control: The QC involved carefully evaluating numerous detailed graphs of daily data to detect evidence of possible quality issues with the data as well as statistically identifying outliers. Each outlier or potential data problem was manually validated using
metadata information of our climate data

With each change or acceptance of an outlier, a record of the decision and the reason behind it was made in the QC log file. QC procedures are:

- If precipitation value is (–), it is assumed as missing value (-99.9)
- If Tmax < Tmin both are assumed as missing value (-99.9)
- If the data outside of threshold (mean ±4*STD) it is assumed as problematic value.

Data homogeneity: A homogeneous climate time series is defined as one where variations are caused only by variations in climate (Aguilar, E. et all, 2004). Data homogeneity is assessed using R-based program, RHtest, developed at the Meteorological Service of Canada (Figure 2). It is based on two-phase regression model with a linear trend for the entire base series (Wang, 2003).
Indices calculation: After the data had been quality controlled and tested for homogeneity, they were ready for calculation of indices. RClimDex creates 27 core climate indices (Table 1).
Kendall's tau based slope estimator has been used to compute the trends since this method doesn't assume a distribution for the residuals and is robust to the effect of outliers in the series. If slope error greater than slope estimate we can't trust slope estimate. If P Value is less than 0.05 this trend is statistically significant at 95% level of confidence (Figure 3).

Table 1. List of the 27 core climate indices

ID	Indicator name	Definitions	UNITS
FD0	Frost days	Annual count when TN(daily minimum)<0ºC	Days
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
ID0	Ice days	Annual count when TX(daily maximum)<0ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
GSL	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC	Days
TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	ºC
RX1day	Max 1-day precipitation	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PR >=1.0mm) in the year	mm/day
R10	Number of heavy precipitation days	Annual count of days when PR >= 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PR >= 20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PR >= nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when PR>95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when PR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (PR>=1mm)	mm

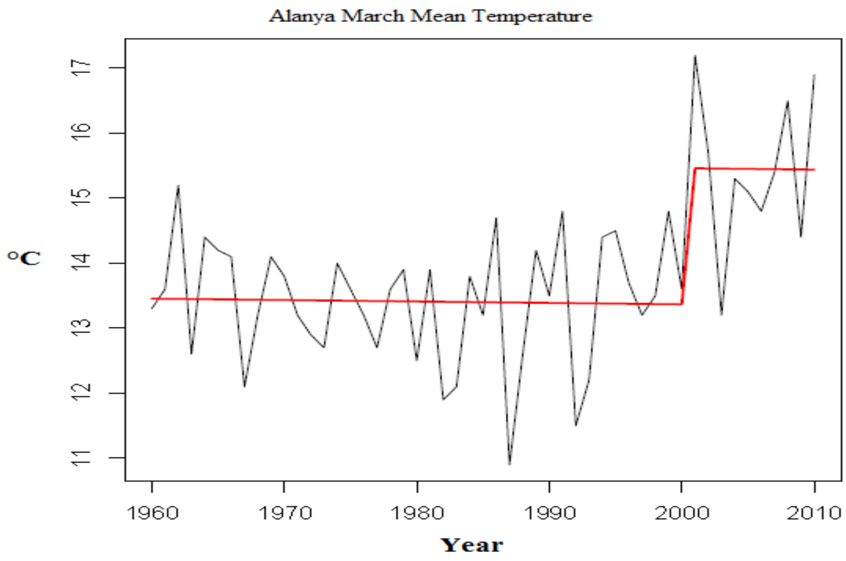

Figure 2. Homogeneity test of March mean temperature for station Alanya, Turkey.

The red line indicates the location and magnitude of possible step changes in the time series and the linear regression across the homogeneous sections between the possible step-change points. Discontinuity indicated by the large step change in the 2000s is not only statistically significant but also verified by the station history metadata, which indicates that the station covered with building.

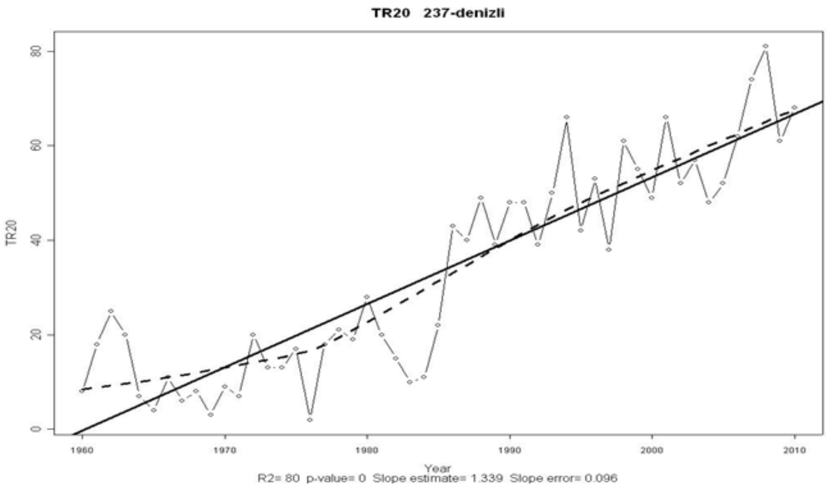

Figure 3. Trend in number of tropical night (Tn > 20°C) in Denizli from 1960 to 2010

This indice plot shows that tropical night will be increased 134 days in 100 years in Denizli and this trend is statistically significant at 95% level of confidence because of P Value is less than 0.05.

Results

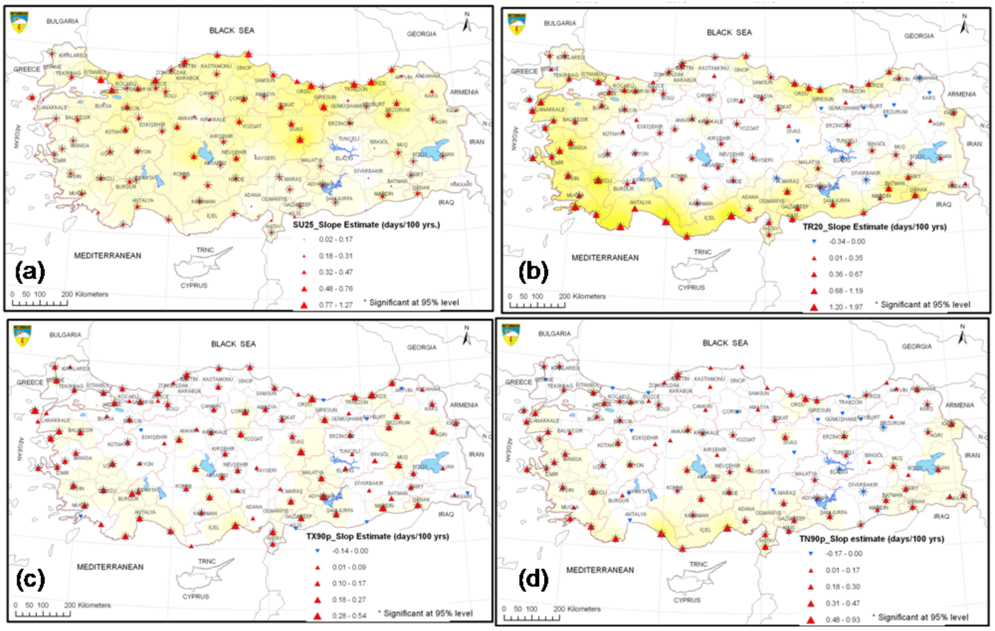

Figure 4. Trends in summer day (a), tropical night (b), warm days (c) and warm night (d)

(a) Numbers of summer days have been increasing all over Turkey especially northern part stations have greatest trends. Kendall’s tau based estimated trend indicates increasing from 1 to 54 days/100 years. Estimated average increasing is 39 days in 100 years. Most of the trends are statistically significant at the 95% level.
(b) Numbers of tropical nights have been increasing except Tigris-Euphrates Basin. Elazığ has significant decreasing trend after Keban Dam constructed. Especially coastal stations have greatest trends. Estimated average increasing is 37 days in 100 years. Most of the trends are statistically significant at the 95% level.
(c) The number of warm days has been increasing all over Turkey. Estimated average increasing is 14 days in 100 years. Most of the trends are statistically significant at the 95% level.
(d) The warm nights have been increasing all over Turkey except Tigris-Euphrates Basin. Estimated average increasing is 15 days in 100 years. Most of the trends are statistically significant at the 95% level.

Growing Season Length has increasing in Thrace, central Anatolia and Eastern Anatolia while decreasing in coastal regions. Warmer temperatures promote increases in plant growth in mid-northern latitudes (Kadıoğlu et al, 2000). Estimated average increasing is 21 days in 100 years. This will be have a positive effect on summer agricultural products but there will be some negative affects will be experienced by orchards which they need chilling requirement.

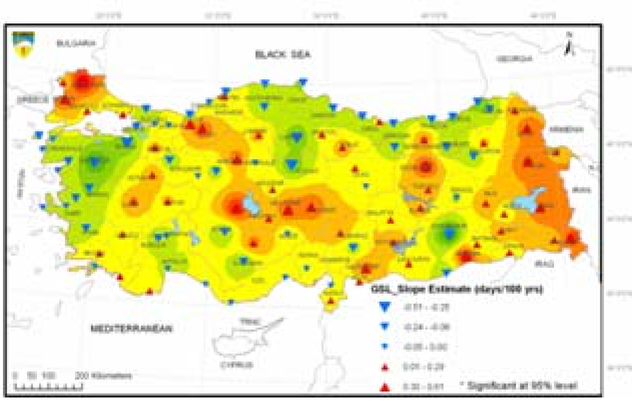

Figure 5. Trends in growing season length

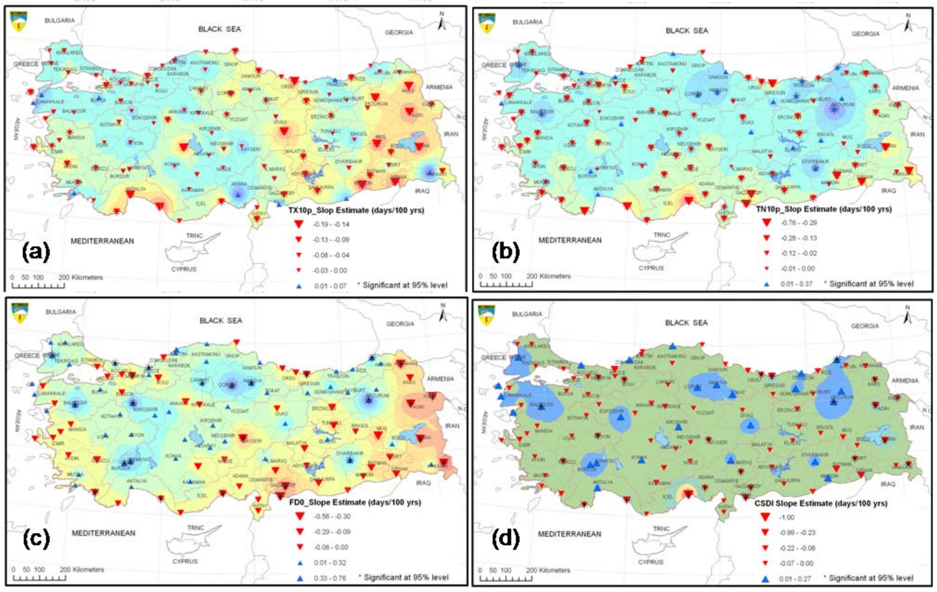

Figure 6. Trends in cool day (a), cool night (b), frost days (c) and cold spell duration index (d)

(a) The number of cool days has been decreasing in most of the stations. Only 10 stations have opposite signal. Estimated average decreasing is 6 days in 100 years. Most of the trends are statistically significant at the 95% level.

(b) The number of cool nights has been decreasing in most of the stations. Only 20 stations have opposite signal. Estimated average decreasing is 15 days in 100 years. Most of the trends are statistically significant at the 95% level.

(c) Numbers of frost days have been increasing mainly in central Anatolia. 53 stations have decreasing trend while 55 are increasing. Projected average decreasing is 14 days in 100 years. Erzurum, Uzunköprü, Çorum, Sivrihisar, Balıkesir, Isparta, Burdur and Diyarbakır show statistically increasing trend.
(d) Cold spell duration index has been decreasing except western part of Turkey, Amasya, Çorum, Eskişehir, Burdur, Erzurum and Bayburt. Projected average decreasing is 20 days in 100 years.

The warm spell duration index have been increasing all over Turkey except Marmaris, Bayburt, Yüksekova, Kilis, Kırklareli, Kayseri, Ceylanpınar and Tunceli. Estimated average increasing is 23 days in 100 years. Most of the trends are statistically significant at the 95% level.

Figure 7. Trend in warm spell duration index

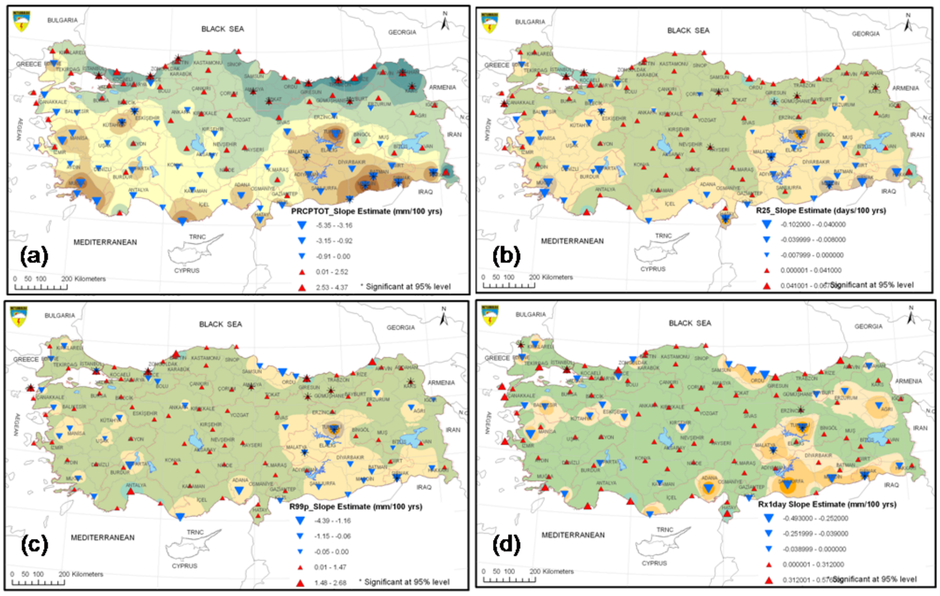

Figure 8. Trends in annual total precipitation (a), numbers of heavy precipitation days (b) very wet days (c) the maximum 1-day precipitation (d)

(a) Annual total precipitation amount is increasing in northern parts of the country while decreasing in Southeastern Anatolia, Mediterranean and Aegean Regions.

(b) Numbers of heavy precipitation days have been increasing in most of the stations except Aegean and Southeastern Anatolia Region. Estimated average increasing is 17 days in 100 years. Eastern Black Sea costs and Southeastern Anatolia have opposite but greater trends.

(c) Very wet days have been increasing in most of the stations except Southeastern Anatolia Region. Estimated average increasing is 119 mm in 100 years.

(d) The maximum 1-day precipitation has been increasing in most of the stations except Southeastern Anatolia Region. Estimated average increasing is 17 mm in 100 years. Mediterranean costs have greater trends.

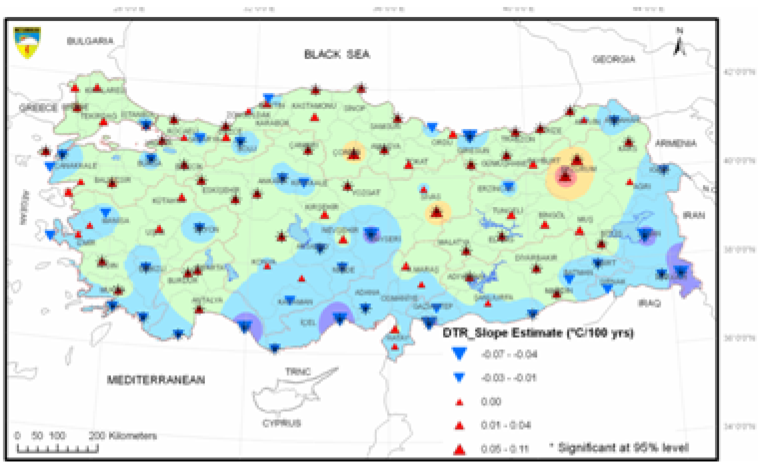

Figure 9. Trend in diurnal temperature range

Diurnal temperature range (Tmax-Tmin) have been increasing in 51 stations while decreasing in 31 stations.

Conclusion

The information provided by the indices not only includes how the mean values changed over time but how the statistical distribution of the data changed. Also results give us very important information about the trends in extremes.

The results show that numbers of summer days and tropical nights have been increasing all over Turkey while frost days decreasing. Summer days have increased about 39 days in 100 years. Most of the trends are statistically significant at the 95% level. Growing season length has increased over Turkey except coastal regions. Warm days and warm nights have been increasing all over Turkey while cool days and cool nights decreasing. Warm spells have increased while cold spells have decreased.

Trend in annual total precipitation is increasing in northern parts of the country while decreasing in Southeastern Anatolia, Mediterranean and Aegean Regions. Numbers of heavy precipitation days have been increasing in most of the stations except Aegean and Southeastern Anatolia Region and usually cause extreme flood events. The maximum 1-day precipitation has been increasing in most of the stations except Southeastern Anatolia Region.

In summary, in general there are large coherent patterns of warming across in the country affecting both maximum and minimum temperatures but there is a much more mixed pattern of change in precipitation.

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