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Seasonality of Precipitation in Turkey: Past, Present and Future Assessments

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ABSTRACT

The objective of this study is to analyze seasonality of precipitation using circular statistics method apart from the other methods in the literature and to investigate changes in seasonality in the future projections. The non-parametric circular statistical method is used to analyze seasonality of precipitation over Turkey for past (1956-1975) and present (1986-2005) periods using both station data and gridded observation data (CRU-3.24). This method is also applied to the CORDEX Europe domain for three different periods which cover early century (2016-2035), mid-century (2046-2065) and end-century (2081-2099) to investigate the potential future changes in the seasonality under a pessimistic climate scenario, CMIP5-RCP 8.5 (Coupled Model Intercomparison Project phase 5-Representative Concentration Pathways 8.5).
Seasonality Index (SI) over Turkey decreases from south (~0.6) to north (~0.1) for past and present periods. For the future periods, SI tends to increase in the south, especially in the south-eastern Anatolian region, while it tends to decrease over the Black Sea and central Anatolian regions. Beside SI, another outcome from the circular statistics is the average occurrence time of precipitation during a year. Winter months (December-January-February) are common occurrence time of precipitation in general for past and present periods. Precipitation occurrence time for the future periods does not change much in the future periods for most of the regions except for the central Black Sea and southeastern Anatolia where it shifts to October and November, respectively.

Keywords: Precipitation, Seasonality, Circular Statistic, CMIP5-RCP8.5

1. INTRODUCTION

Precipitation is one of the important components of the hydrological cycle for the activities from fundamental needs to agriculture in human life. Therefore, it is important to know its behavior in the past and present and its possible changes in the future. Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report [9] demonstrated that observations in precipitation trends from 1900 to 2005 differ region to region, for instance; significantly positive trends have been observed in eastern north and south America, northern Europe and northern and central Asia, but trends are negative in Sahel, south Africa, the Mediterranean and southern Asia.
Mediterranean is one of the vulnerable regions to climate change according to IPCC reports [10], [11]. There are several studies focusing on the Mediterranean Basin since predictions from

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different climate scenarios point out that the region might be severely affected by global climate change [7]. Mariotti et al. [15] studied the effects of individual hydroclimatic changes over the Mediterranean region by using CMIP3 multi-model simulations. Their results show that reduction in precipitation which has already started in the 20th century will be in larger amounts in the 21st century. Decreasing precipitation trend in the eastern and southern Mediterranean from October to May for the period 2071-2100 was presented by Hertig & Jacobeit [9] who applied statistical downscaling techniques to Mediterranean precipitation obtained from SRES scenarios. Also, Ozturk et al. [19] studied changes in both temperature and precipitation in the future of 2070-2100 using CMIP3 datasets for SRES A2, A1B and B1 emission scenarios respect to period of 1970-2000. They concluded that dryer climate conditions control the Mediterranean Basin and also intensity and frequency of extreme precipitation events might likely increase in the future [19].

Recently, plenty of regional model studies focusing on the eastern Mediterranean are conducted to understand the performance of the regional models in simulating the reference period climate ([6], [1]) and the future changes in temperature, precipitation and hydroclimatic variables, especially for Turkey ([14], [17], [18], [2], [4]).

Beside investigations on precipitation changes under future climate scenarios, trends of precipitation have been studied by using observations for Turkey. Different statistical methods, such as; principal component analysis (PCA), clustering or Mann-Kendall test, have been applied to station based data. Rainfall regions were classified by Turkes [22] in seven regimes for the period 1930-1993. Mann-Kendall test pointed out decreasing precipitation trend in the Black Sea and Mediterranean rainfall regions. Principal Components (PCs) of seasonal precipitation were analyzed first four components by Kadioglu [12]. According to this study, the first component explains meteorological processes (for instance cyclonic activities in winter and autumn), second PC shows continentality and third one explains the effect of surrounding seas of Turkey.

Partal & Kahya [20] determined trends applying Mann-Kendall and Sen's T tests to station data spanning from 1929 to 1993. They found significant decrease in precipitation in western and southern Turkey, and along the coasts of the Black Sea. They also identified significant trends in January, February, and September and in the annual means.

Turkes et. al., [24] applied PCA (Principal Component Analysis) to station data for the period 1953-2002 to analyze long-term changes in precipitation for monthly, seasonal and annual time series. The study revealed decreasing trend for the studied period in winter all over Turkey while it increases in spring, summer and autumn. It is also concluded that the strong decline in precipitation is found over the Mediterranean and Mediterranean transition rainfall regime regions, and they implied that strong precipitation decreases are observed all winter months in a year while increasing trends are observed at some stations in April, August and October. Spatial structure of seasonality and magnitude of precipitation are explored by Saris et al., [21] using multivariate classification methodology. They concluded that seasonality and magnitude of precipitation change depending on Polar and Subtropical Jets and topographic complexity. Annual precipitation was classified in three groups for Turkey; 1) coastal regime along the coastlines of Turkey, 2) inland regimes over central and eastern Anatolia, 3) transitional regime in southeast Anatolia and inland Aegean region [21]. Gokmen M. [8], compared two reanalysis datasets (ERA-Interim and ERA-Interim/Land) for some hydroclimate variables. They found that ERA-Interim dataset shows significant decrease in precipitation in southeastern and northeastern Anatolia, however, ERA-Interim/Land indicates minor or no decreasing trends for southeastern Anatolia region and increasing trend in the northeastern region. Comparing these two reanalysis datasets with observation data indicates that ERA-Interim/Land is relatively close to observations. Both datasets show significant increases in the western part of Turkey.

In this study, we utilized observation data, CRU gridded global precipitation data and future scenario datasets from CORDEX Europe domain to analyze Seasonality Index and average time of occurrence of precipitation by applying circular statistics to the datasets by splitting them in different periods. Therefore, we are able to compare past and possible future changes in precipitation seasonality and timing in Turkey.

2. DATA AND METHODOLOGY

2.1. Datasets

In this study, three different datasets are used calculating circular statistic. One is station data served by Turkish State Meteorological Service. The method is employed for 81 stations selected to represent each province of Turkey (Figure 1). Available length of the data limits selection of stations. Second is global gridded data with 0.5 degree by 0.5 degree horizontal resolution provided by Climatic Research Unit [3]. CRU.3.24 version is used as gridded observation data to compare with station data for two 20-year periods; one is past between 1956-1975, and the second period is present between 1986-2005 based on the latest IPCC report.

Figure 1. Station locations used for analysis

As a third dataset, CORDEX regional model runs belong to sixteen different simulations given in Table1 used for detecting future changes in SI and average time of occurrence. These CORDEX simulations are forced by RCP 8.5 scenario which points out a dramatic increase in CO_2 concentration. RCP 8.5 forced CORDEX data is split into three periods abide by IPCC: present century (2016-2035), mid-century (2046-2065) and end-century (2081-2099). Horizontal resolution of the CORDEX data is 0.5 degree by 0.5 degree and GCM (Global Climate Model) forcing models and RCMs (Regional Climate Model) used simulating the CORDEX domain are given in Table 1 [13].

Table 1: CORDEX datasets used in the study

Forcing GCM	Regional Model
CCCma-CanESM2 r1i1p1	SMHI-RCA4
CNRM-CERFACS-CNRM-CM5 r1i1p1	SMHI-RCA4
CNRM-CERFACS-CNRM-CM5 r1i1p1	CNRM-ALADIN53
CSIRO-QCCCE-CSIRO-Mk3-6-0 r1i1p1	SMHI-RCA4
ICHEC-EC-EARTH r12i1p1	SMHI-RCA4
ICHEC-EC-EARTH r1i1p1	KNMI-RACMO22E
ICHEC-EC-EARTH r3i1p1	DMI-HIRHAM5
IPSL-IPSL-CM5A-MR r1i1p1	SMHI-RCA4
MIROC-MIROC5 r1i1p1	SMHI-RCA4
MOHC-HadGEM2-ES r1i1p1	SMHI-RCA4
MOHC-HadGEM2-ES r1i1p1	KNMI-RACMO22E
MPI-M-MPI-ESM-LR r1i1p1	SMHI-RCA4
MPI-M-MPI-ESM-LR r1i1p1	MPI-CSC-REMO2009
MPI-M-MPI-ESM-LR r2i1p1	MPI-CSC-REMO2009
NCC-NorESM1-M r1i1p1	SMHI-RCA4
NOAA-GFDL-GFDL-ESM2M r1i1p1	SMHI-RCA4

SI and average time of occurrence calculations for the future are employed after eliminating the systematic error comes from CORDEX data using present periods of CRU data as given in equation 1. This approach is necessary and very useful to make right interpretation for the future changes. The following procedure is applied to the CORDEX data:

$$Model=(M_{future}/M_{present})*OBS \quad (1)$$

where OBS is CRU data, and $M_{present}$ is the ensemble mean of the CORDEX data for period 1986-2005 and M_{future} is each of three future periods; present-century, mid-century and end of century. Hence, we can calculate possible changes in the future according to defined period for present and/or past periods.

2.2. Methodology

Circular statistics is applied to precipitation data which is one of the most important hydrological variables. Two values are obtained from the circular statistics; one is SI and the second one is average occurrence time of precipitation over a year. SI, a simple approach to quantify the time of occurrence of an event, is proposed by Markham [16]. Mean monthly values of variable which is precipitation in the study are represented as vectors. Magnitude and direction of the vectors represent the mean monthly values (SI) and their time of occurrence over the year in this approach. The average time of occurrence is akin to the arithmetic mean and SI is akin to the standard deviation for noncircular variables [5].
Each month are represented on a circle depending on an angle given in Table 2. Direction of the angle is measured from 1^{st} of January to mid-month given by Table 2 (adopted from [5]). Hence, monthly precipitation is assigned as a vector and its length is proportional to the amount and a

direction as given in Table 2. The vector direction ϕ_R *and* the magnitude P_R are calculated as:

$$\phi_R' = tan^{-1}\left(\frac{S}{C}\right) \quad (2)$$

$$P_R = (S^2 + C^2)^{1/2} \quad (3)$$

$$S = \sum_{m=1}^{12} P_m . \sin(\phi_m) \quad (4)$$

$$C = \sum_{m=1}^{12} P_m . \cos(\phi_m) \quad (5)$$

where the P_m is monthly precipitation data and the ϕ_m is the 12 monthly time angles given in Table 2. The average time of occurrence ϕ_R is calculated by considering signs of S and C which determine the resultant vector in the quadrant of the circle.

$$\phi_R = \phi_R{}' \quad \text{if S > 0 and C < 0} \quad (6)$$

$$\phi_R = \phi_R{}' + 180^o \quad \text{if C < 0} \quad (7)$$

$$\phi_R = \phi_R{}' + 360^o \text{ if S < 0 and C >} \quad (8)$$

ϕ_R can be represented as the month using the last column of the Table 2. The SI is the ratio of P_R *to* the average annual precipitation. SI ranges from 0 to 1 that means that precipitation is equal in all months and precipitation is observed in a single month, respectively.

Table 2: Angles and their functions for computing SI and average time of occurrence for monthly data [5]

	First of Month			
Month	First of Month	Angle (degrees)	Sine	Cosine
January	1.0	15.8	0.272	0.962
February	31.6	44.9	0.705	0.709
March	59.2	74.0	0.961	0.276
April	89.8	104.1	0.970	-0.243
May	119.3	134.1	0.718	-0.696
June	149.9	164.2	0.272	-0.962
July	179.5	194.3	-0.246	-0.969
August	210.1	224.9	-0.705	-0.709
September	240.7	255.0	-0.966	-0.260
October	270.2	285.0	-0.966	0.259
November	300.8	315.1	-0.706	0.708
December	330.4	345.2	-0.256	0.967

3. RESULTS

Basically, we focus on three different periods; past, present and future while analyzing the precipitation data over Turkey. Past and present periods are defined between 1956-1975 and 1986-2005, respectively. Future periods are defined based on the recent IPCC report. Thus, changes of SI and average occurrence time are analyzed for three periods, 2016-2035, 246-2065 and 2081-2099 in the study.

3.1.1. Past and present periods

SI distribution over Turkey is given by station data and gridded CRU data in Figure 2a which indicates the broad agreement between these two datasets for period 1956-1975. Higher SI values could be seen from the west to the southeast of Turkey for the past. Gradual decrease in SI is seen towards north. SI is low over the Black Sea coast from the east to the west up to Zonguldak, however, the lowest SI values are observed in the northeast part of the region. It is between 0.2-0.4 over central Anatolia and it gets lower in the eastern Turkey. General graded decrease towards north in SI, which is also the main behavior for present period (1986-2005), can be seen in Figure 2b. However, SI in present period declines all over Turkey, for instance, central Anatolia experiences decreases in SI between 0.1-0.2 in a very large area. In this period, lower SI values are also observed over the central Black Sea in addition to the northeastern Black Sea part. During this period, SI values, calculated from station data and CRU data show some discrepancies, for example, in the central Anatolia some of the stations have lower SI values than the CRU or in the northeastern Black Sea border CRU has lower SI than the stations.

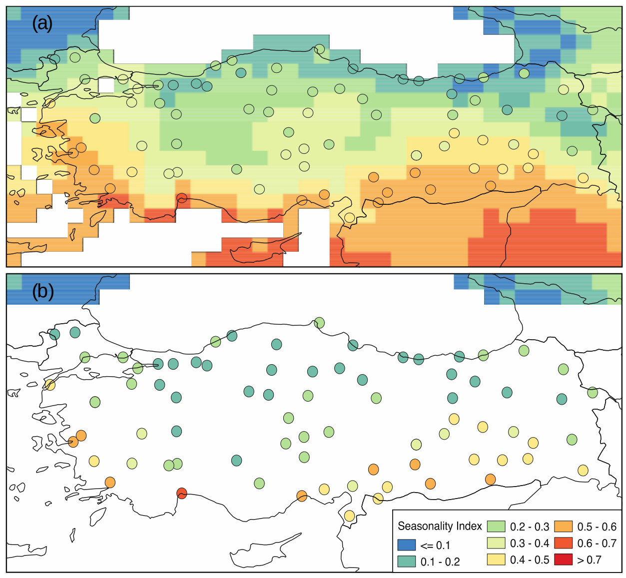

Figure 1.SI for a)1956-1975 and b) 1986-2005) from station data (represented by circles) and CRU gridded data (represented by area cells)

Concisely, distribution of SI indicates that precipitation is observed almost uniformly in the year over the Black Sea coast while it occurs in certain months rest of the country. This structure is in agreement with findings obtained by Turkes [23].

3.1.2. Future periods

Similar to past and present periods, SI shows a decreasing trend from south the north over Turkey in the future periods. In this sub-section, we present SI differences between the past (and also present period) and the defined future periods which are computed based on the worst-case climate change scenario introduced by IPCC.

3.1.2.1 Early century (2016-2035)

Figure 3a shows no SI changes in western Turkey in general. SI slightly increases only in Canakkale and Erdek. In the north through the Black Sea coast, slight decrease in the central part and increase in the eastern Black Sea can be observed. The east and southeast Anatolian part indicate increases in SI, however it is interesting to behold a decrease near the southeastern border of Turkey. It behaves in an opposite manner from its near-by areas. Comparison with period 1986-2005 indicates that increase in SI difference expands over Turkey except the southeastern Turkey. SI declines in the southeastern region similar to the past (Figure 3a, b). SI sustains its behavior in this period observed in Figure 3b through the Black Sea coastline from central part to the east.

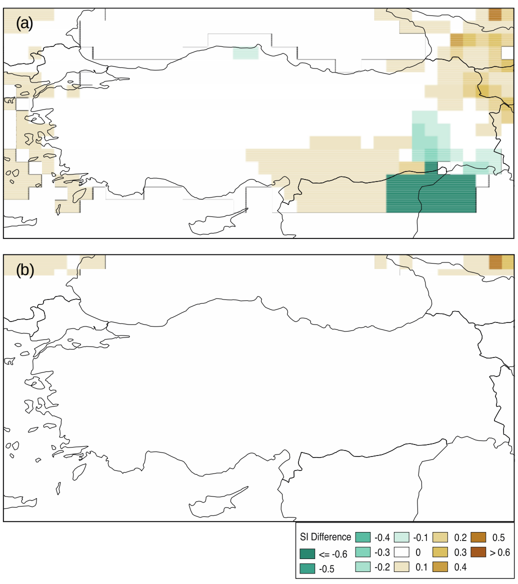

Figure 3. SI difference a) between 2016-2035 and the past period (1956-1975) and b) difference between 2016-2035 and the present period (1986-2005)

Turkes [23] emphasized that number of depressions in autumn and winter which follows the paths originate from Gulf of Genoa through Adriatic Sea and from North Atlantic through Balkans to Turkey decreased in late 1970s to 1990s. Therefore, frequency changes in depression contribute to increase in SI for the present period.

3.1.2.2 Mid-Century (2046-2065)

Seasonality of precipitation in mid-century demonstrates changes from the early century according to our analysis that is exhibited in Figure 4. If we compare SI changes of present and mid-century from the past period which are seen in Figure 3a and Figure 4a, it could be clearly observed that there is a reduction along the Black Sea region, especially in the central part towards inland in the mid-century. SI difference raises only around the northeast border of Turkey, surrounding areas of Agri and Igdir. SI decreases in the southeast similar to that in the early century with less coverage observed in Figure 4a. On the other hand, Figure 4b shows that no common decreasing SI signal can be seen in the present period as it is seen in Figure 4a. Conversely, SI increases in the south, Mediterranean and Aegean coasts, and northeast. Additionally, SI increases in Istanbul and its western neighbor and also in the vicinity of Sinop. Although, seasonality index declines in the southeast as similar to the past period, its expansion is very close to Iraq and Syrian border of the country.

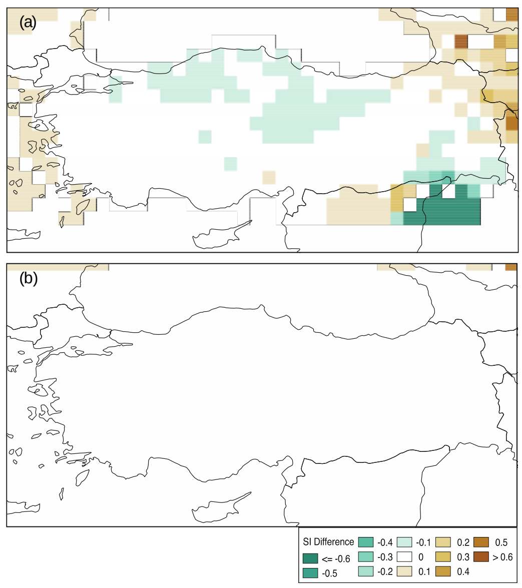

Figure 4. SI difference a) between 2046-2065 and the past period (1956-1975) and b) difference between 2046-2065 and the present period (1986-2005)

SI decreases in the mid-century if we compare with early-century in general and this points out that precipitation will be seen in a longer period not only in a few months. Shifting north-south direction of depressions or dominant pathway of cyclones and their frequency and also increase in convective activities in spring and summer months might contribute on decrease in SI.

3.1.2.3. End-Century (2081-2099)

In general, seasonality indices in the end-century over Turkey shortly indicate similarity to mid-century (Figure 4 and Figure 5). Namely, SI difference gets lower in the past periods along the Black Sea coast mostly, however, for the present periods situation reverses, and SI increases almost all over Turkey. If we make comparison between the past and present periods specifically for the end-century, decreasing SI in the past period reaches from the Black Sea to the central Anatolian region (in Figure 5a). There are also decreases in a small part of the Marmara and west Anatolian regions. Eastern Anatolia has more increasing trend in SI changes and it is largely located in the southeastern and northeastern part of Turkey. Decreasing SI changes in the southernmost location tends to disappear in the end-century (in Figure 5a) in comparison to the mid-century (in Figure 4a).

Increasing SI changes is common over Turkey especially in the south and the eastern parts as similar to mid-century (Figure 5b and Figure 4b, respectively). There is such a difference between mid and end century is that increasing SI in the southeast border of the country is not wider in the end-century. On the other hand, there is no change in the west and over the Aegean Sea in the end-century unlike the mid-century in which SI increases.

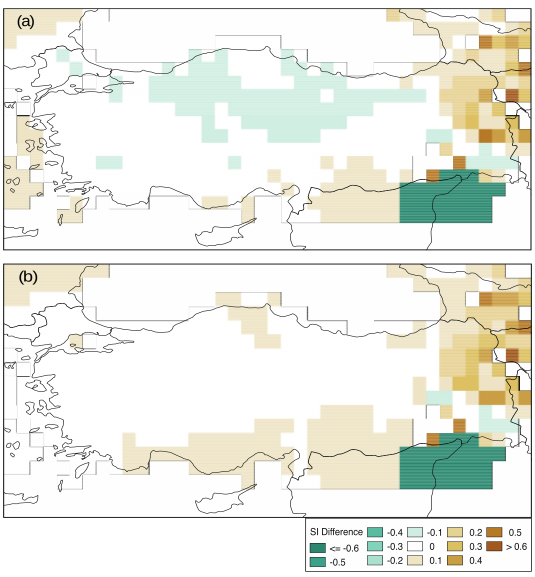

Figure 5. SI difference a) between 2081-2099 and the past period (1956-1975) and b) difference between 2081-2099 and the present period (1986-2005)

3.2. Average time of occurrence analysis

Two values are obtained from the circular statistics: The first one, SI, is given in the previous section, and the second one, average occurrence time of precipitation over a year, will be given in this section.

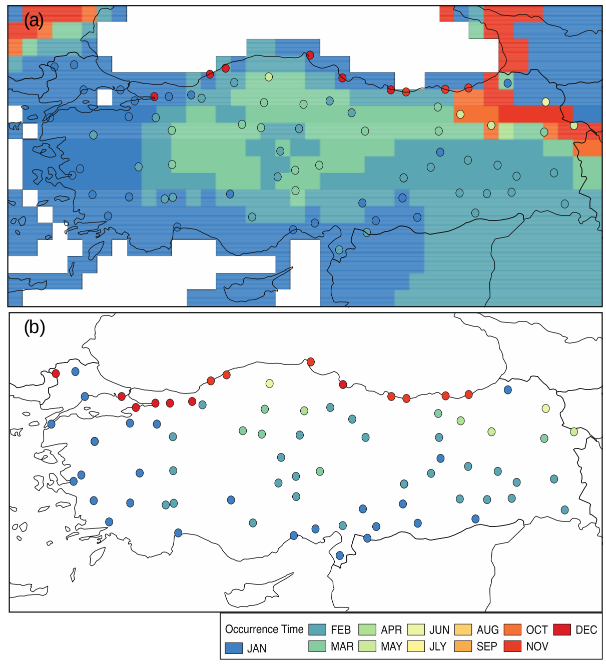

Figure 6. Average time of occurrence of precipitation for a) the past period 1956-1975 and b) the present period (1986-2005). Circles represents average time of occurrence at stations.

3.2.1. Past and present periods

Figure 6a and 6b show the average time of occurrence over Turkey based on station data and gridded CRU data. Statistical analysis from CRU points out that occurrence time of precipitation is January along the shoreline and, occurrence time shifts to February or March if we move inland. Average occurrence happens in October and November for the northeastern Turkey and also the easternmost Black Sea region. There is an outstanding discrepancy observed between the station and CRU data over the Black Sea coast. Occurrence time from the station data is December in the west and central Black Sea and it is in November in the east except for Artvin which is January for this station in the past period. Five stations indicate quite a different behavior from the other stations. The average occurrence time is May four out of five, Kastamonu, Bayburt, Erzurum, Igdir, and, it is July for the station Agri from the station dataset. However, unlike station data, CRU analysis indicates that occurrence time takes place in winter or autumn months for these stations (in Figure 6a). Different average occurrence time between observed and gridded data (CRU) comes from the horizontal resolution difference. Station data reflects more local features while gridded data smooth out the local properties and gives average behavior of the area.

General occurrence time distribution for the present period is very similar to the past period (in Figure 6b). Same difference between the station and CRU datasets for the Black Sea coast and five stations given in the previous paragraph are still observed for this period as well. However, only two cities, Samsun and Artvin, on the Black Sea coast maintain their occurrence time, the rest of the stations shifts back to November their occurrence time in the present period. Stations in the Marmara region (e.g., Edirne, Istanbul, Yalova, Adapazari) shift one month back to December from January in the present period. Shift of average time of occurrence in these stations might be attributed to changes in the path of depressions which does not analyzed in this study. For example, the path of depressions originates from North Atlantic and Balkans [23] enters into Turkey from Edirne and it passes over Istanbul, Izmit Adapazari. Therefore, this path (which was identified as path II in [23]) might be dominant in the present period with little changes in its north-south direction. On the other hand, there is no shift observed in CRU gridded data for this region. The occurrence time of precipitation retreats to February in the central Anatolia for 1986-2005 period while it appears in March for 1956-1975 period. Also, CRU indicates one month shift in the southeastern Anatolia (from February to January), although such changes are not monitored in the station data (Figure 6b).
Figure 6a and 6b indicates sharp difference between the coastal region and inland. As it is also mentioned in the previous studies ([23], [21]), this pattern shows that synoptic scale weather patterns affect the coastal region while the continentality and topography are the important factors through the inland.

3.2.2. Future periods

Average time of precipitation occurrence is analyzed for three future periods as in seasonality index. Namely, circular statistics are applied to the CORDEX RCP8.5 scenario simulations to have information about precipitation behavior in the future.

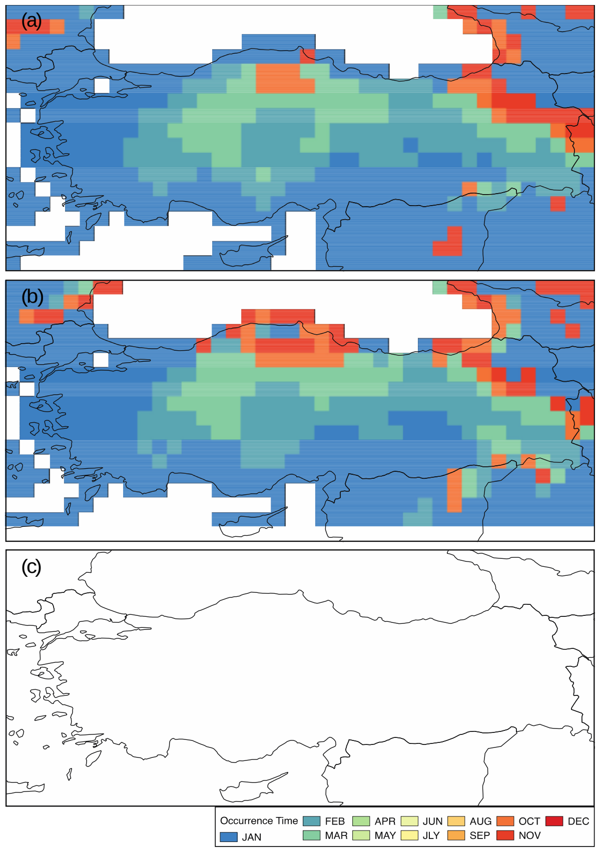

Figure 7. Average time of occurrence of precipitation for a) the present century (2016-2035), b) the mid-century (2046-2065), and c) the end-century (2081-2099)

Early century (2016-2035)

Occurrence time of precipitation in coastal areas has a similar distribution to the past and present period in Figure 7a. The most striking regional changes are observed in the central Anatolia and the southeastern border of Turkey from the circular statistics (in Figure 7a). Tendency of occurrence time over the most of the central Anatolia is the shifts forward a month (from February to March). But there is inland part of the central Black Sea over which occurrence time switches to October (from March). Broad range of occurrence time, for instance, October, January, February, March, is seen on the adjacent grids over the border of southeastern part in the present century period.

Mid-century (2046-2065)

Time of the precipitation occurrence is January along the Mediterranean Sea, the Aegean Sea and the western Black Sea coasts. This feature does not change almost all the periods that have been analyzed in this study. Also, occurrence time in the central Anatolia in the mid-century is February and March as similar to that in early century. The most significant changes in the central Black Sea are monitored in this period (Figure 7b). It appears that this region is very sensitive to changes in climate. Average time of occurrence changes to October and November in mid-century. Other regions sensitive to occurrence are the east Anatolia and the eastern Black Sea indicating that the time of occurrence retreats to January in the eastern Anatolia and it changes to October and November in the eastern Black Sea.

End-century (2081-2099)

Southern coast of Turkey, the Mediterranean Sea and the Aegean Sea conserve the month January as the average time of occurrence in the end-century. Also, January is the month precipitation occurs in the Marmara region as similar to the south coasts. Exceptionally, it is November in Istanbul, and the west of Black Sea (Figure 7c). Precipitation occurrence time shifts to February-March from October-November over north of the central Black Sea. Figure 7c indicates that the eastern Black Sea and the eastern and southeastern Anatolian regions change in this century. Although occurrence time is changing between October and November in the mid-century, it turns to March over some grids in the end-century. On the other hand, average time of occurrence switches mostly backward to months, October and November over the eastern Anatolian region.

4. CONCLUSIONS

In this study, we assessed the changes in seasonality index and average occurrence time of precipitation in a yearly time basis over Turkey, one of the countries in eastern Mediterranean which is vulnerable to climate change in the future according to IPCC reports. Assessment of SI and occurrence time was conducted for three 20-year periods; past (1956-1975), present (1976-2005) and future (2016-2099). Future period is also composed of early century (2016-2035), mid-century (2046-2065) and end-century (2081-2099) sub-periods.

Both station observations and CRU dataset give out similar distribution of SI over Turkey for the past and present periods in general. It should be kept in mind that comparison between the gridded CRU data and point (station) data can results in such difference since their horizontal resolutions are unlike. Therefore, local properties of an area do not well capture by CRU data while observation data retain local properties of the station (e.g., complexity of topography).

A characteristic behavior of SI is that it decreases from south to north of the country. Lower SI values take place over the Black Sea coast (except Black Sea coast of the Marmara region) of Turkey which implies that precipitation can be observed almost all months of the year. However, SI indicates that precipitation can be observed in a few months on the south. Difference between south and north of Turkey is obvious in the present period. SI declines overall the northern Black Sea coast including northern Marmara region while it rises in west and south. The central Black Sea coast is the outstanding region with decreasing SI for the present period.

SI for near future period (2016-2035) in southeastern and northeastern parts of Turkey indicates changes over the past and present periods. The main change is observed in the southeastern Anatolia with increasing SI while it decreases in the northeastern part. SI increase in southeast border and decrease in east-northeast borders of the country for present period are similar to past period. SI changes between end-century and present depict similar pattern for mid-century which shows increasing SI through the eastern border. However, SI changes in a big range over the southeastern region. It means that precipitation might occur either almost all months or a few months in a year. Continentality, local topographical complexity and synoptic scale weather conditions are the factors which control the occurrence time and annual pattern of precipitation.

Second variable obtained by circular statistics, which is average time of precipitation occurrence in a year, shows a different pattern between station data and CRU dataset. General pattern depicts that precipitation occurs in January from south coast to Marmara region and also some part of the Black Sea for the past and present periods calculated by using CRU dataset. Nevertheless, it is November or December from station data at the Black Sea coast. February and March are the occurrence month in Central Anatolia both for past and present periods. CRU is in line with most of station data in this region, although at some stations it is far from what is expected (such as, precipitation occurs in June in Kastamonu according to station data). This might happen due to a deficiency in station data. Same disparity is valid at stations Ardahan and Igdir in the east while October and November are months for the rest of the northeastern border.

Average time of occurrence in precipitation for three future periods in west-southwest of Turkey indicate no difference from the present and past periods. Important variability observed in the central Black Sea and southeastern Anatolia. Occurrence time of southeastern Anatolia shifts back to October and November in the end-century. It switches back and forth from near future to end-century. These two regions seem to be very sensitive to climate change according to applied statistical approach. The position of the cyclone paths and the number of depressions might affect seasonality of precipitation especially on the coasts. Complexity of topography and continentality are important factors through the central and eastern Anatolia. Characteristics of the paths and local features (topography, continentality etc.) also play a role on shifting the average occurrence time of precipitation especially in the eastern Anatolia and the Black Sea.

Although shift of the depression path is not examined in this study, changes of the position or frequency of the depressions should be investigated using future projections that might give more information while attempting to explicate relation between seasonality, occurrence time and magnitude of precipitation and atmospheric dynamics. Therefore, as a future work, high resolution RCM simulations (higher than CORDEX horizontal resolution) might give more information about seasonality of precipitation and also time of occurrence under different future climate change scenarios either using available CMIP5 data or new generation CMIP6 experiments which would be available near future.

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