Environment and Natural Resources Research; Vol. 6, No. 4; 2016
ISSN 1927-0488 E-ISSN 1927-0496
Published by Canadian Center of Science and Education

Heavy Precipitation Events in Marmara Region and connections with the North Atlantic and Arctic Oscillation Patterns

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Received: August 9, 2016 Accepted: September 23, 2016 Online Published: October 17, 2016

doi:10.5539/enrr.v6n4p1 URL: http://dx.doi.org/10.5539/enrr.v6n4p1

Abstract

The prediction and understanding of the extreme weather events became one of the top priorities of the forecasting centers. To analyze the heavy rainfall events, the data from reanalysis and station datasets are utilized. The linear regression analysis and principle component analysis (PCA) are applied on precipitation, temperature, Arctic Oscillation Indices (AO) and North Atlantic Oscillation Indices (NAO) datasets. The results indicate that the relationship between these variables can be expressed neither by linear regression nor by PCA, which falls in short in capturing the complexity of the problem. The results indicate the importance of low-level jet in two cases out of three cases considered here.

Keywords: Heavy Rain, Extreme Weather Events, Low Level Jet

1. Introduction

Extreme weather events have significant effects on both the society and the individual which makes it important to understand and predict them correctly. These events are affected by a wide range of factors from topography, local forcing to remote teleconnection patterns such as El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO). On the other hand, extreme precipitation events such as flash floods, heavy rain may sometimes intensify low-level jets in the troposphere (Diaz & Murnane, 2008).

The climate of a region is affected by its geographical location and the geographical features of its surroundings. Large surfaces of land and water such as continents and oceans affect the air mass above it via their radiation balance (incoming, absorbed & reflected radiations). The climate of Turkey is affected by four air masses, namely: cP (Continental Polar, originates from Siberia), mP (Maritime Polar; originates from the northern part of Atlantic Ocean), mT (Maritime Tropical; originates from the equatorial part of Atlantic Ocean, Mediterranean and Aegean seas), cT (Continental Tropical; originates from North Africa) (Türkes, 1996; Sirdas, 2003). Precipitation is an important parameter which is directly affected by the climate of a region. In other way, by using the precipitation data, the climatological characteristics of a region can be determined. Due to its geographical location, Turkey receives rainfall throughout the year with varying intensity of precipitation over the country e.g. a city in the East Black sea region of Turkey receives 2200 mm of precipitation annually, while another one in Central Anatolia receives only 320 mm of precipitation (Sirdas, 2003; Sirdas & Sen, 2003).

Extreme weather events such as floods, droughts, heat waves and tropical cyclones are related to the climate and somehow linked with the recent global climate change. Furthermore, it is difficult to state that each and every one of the event is an indication of a change in the climate. As Mark Twain once said “The climate is what we expect and the weather is what we get”. Extreme weather events can be separated in two groups: firstly, weather-based events relatively short-termed events which can be predicted 1-2 weeks ahead such as tropical cyclones, severe floods etc; secondly, climate-based events such as drought, season-long heat waves, multiple occurrences of severe storm events and record wildfire (Diaz & Murnane, 2008). Extreme weather events occur due to the complex interactions between large-scale atmosphere-ocean circulation patterns such as the Arctic Oscillation, El-Niño-Southern Oscillation with local weather (Khandekar, 2013). Most of Indian summer monsoonal droughts are associated with an El-Niño of the central-eastern Pacific Ocean (Khandekar & Neralla, 1984; Yarav, Ramu, & Dimri, 2013; Kumar, 2016). ENSO has also been correlated to the droughts in Amazonia region, while floods in south-eastern region of South America (Cavalcanti, 2012). Martin & Schumacher (2011) found negative correlation between the Caribbean Low-Level Jet (CLLJ) and Caribbean precipitation based on model study. Although, in many other cases as well low-level jets have been found to relate to the extreme precipitation events, somehow the correlation between the low-level jets and precipitation events is hard to establish. Lazarus (2009) states that during El Niño years, the precipitation observed in Florida increases where suppresses during a La Nina years. There are many studies, those explain rainfall prediction and variability on the scale of time and space over Euro-Mediterranean region (Sirdas et al., 2007), Iran (Amiri, Amerian, & Mesgari, 2016); Amiri & Mesgari 2016) and India (Kumar & Krishnamurti, 2012; Kumar & Krishnamurti, 2015).

Precipitation extremes are statistical anomalies of a log-normal probability density function over a region (Sirdas et al., 2013). These extremes have been found to be affected by a plethora of factors, such as sea surface temperatures (SST) anomalies (Grimm & Tedeschi, 2009), teleconnection patterns (Vasconcellos & Cavalcanti, 2010), synoptic systems like frontal systems (Vasconcellos & Cavalcanti, 2010), persistent systems (Carvalho, et al. 2002) and large mesoscale convective systems (MCSs) (Durkee, et al. 2009) in their study of South American climate. Haylock & Goodess (2004) demonstrated a link between NAO and extreme precipitation in winter (DJF) by examining two indices of dry-days and wet-day from the data of 347 stations over Europe. A sign of negative NAO has an impact on the storm track in eastern tropical Pacific and western Atlantic (Cassou, 2008). Furthermore, this study demonstrates a link between MJO (Madden-Julian Oscillation) and NAO, based on daily geopotential height maps from 1974 to 2007.

This study begins by summarizing elementary information on the difference between weather and climate and gives what are the elementary parts of the climate extremes in Turkey. Further an attempt is being made to introduce the concept of extreme weather and its association with certain mesoscale convective systems such as ENSO and NAO. The purpose of this study is to analyse the relationship between teleconnection patterns (namely the AO and the NAO) and statistically extreme precipitation events (such as heavy rains). In the last section the manuscript comprises, 3 case studies to examine a physical relationship between the low-level jets and extreme precipitation events.

2. Data & Distribution Analysis

2.1 Locations of Meteorological Stations

The following section focuses on the analysis of the monthly precipitation and daily temperature data from 23 meteorological observation stations in the Marmara region. The duration of this dataset is 40 years (1970-2010). This study comprises the average precipitation received by each station, total precipitation received by each station, and total precipitation received during 1970 to 2010. The meteorological observation stations mentioned above are: Ayvalık, Bandırma, Bursa, Balıkesir, Bozcaada, Çanakkale, Çorlu, Dursunbey, Edirne, Edremit, Florya, Geyve, Gönen, Kartal, Keleş, Kireçburnu, Kırklareli, Kocaeli, Kumköy, Lüleburgaz, Sakarya, Şile and Tekirdağ. Figure 1 shows the geographical locations of 23 stations.

2.2 Data Analysis of Meteorological Station Data

Datasets from 23 stations of Marmara region have been analysed to find the good cases those would show a dynamical relationship between the oscillations and the extreme weather events. The temperature and total rainfall data have been studied on a monthly basis to understand their variability. Some of the special cases of temperature are also studied on a daily basis to layout the relationship between the cases and the oscillations.

The amount of precipitation received by Marmara Region varies from January to December months and is lowest for summer season. Majority of stations show maximum annual precipitation is being received in autumn (SON) and winter (DJF) months. Generally, the amount of precipitation ranges between 0-100 mm in summer (JJA) months to a peak of 400-450 mm in winter (DJF) months, while the spring (MAM) months and autumn (SON) months lying in between. In general, autumn months having more precipitation than spring months. Turkey receives most of the precipitation during autumn (SON) and winter (DJF) months (Figure 2). There are some extreme cases in which Şile received the highest precipitation, more than 300 mm of precipitation in the month of August e.g. 1997. Such a heavy rainfall in the month of August is anomalous. The high peaks (Fig 2) indicate to an extreme weather event as compared to lowest peak in the summer months. However, the coastal provinces such as Edremit, Çanakkale, Ayvalık and Bandırma show gradual change in the precipitation, while the provinces away from sea such as Sakarya, Balıkesir, Keleş and Dursunbey show a dramatic change in the precipitation regime, between spring (MAM) and summer (JJA) months.

Figure 1. Map showing the locations of the Meteorological Stations

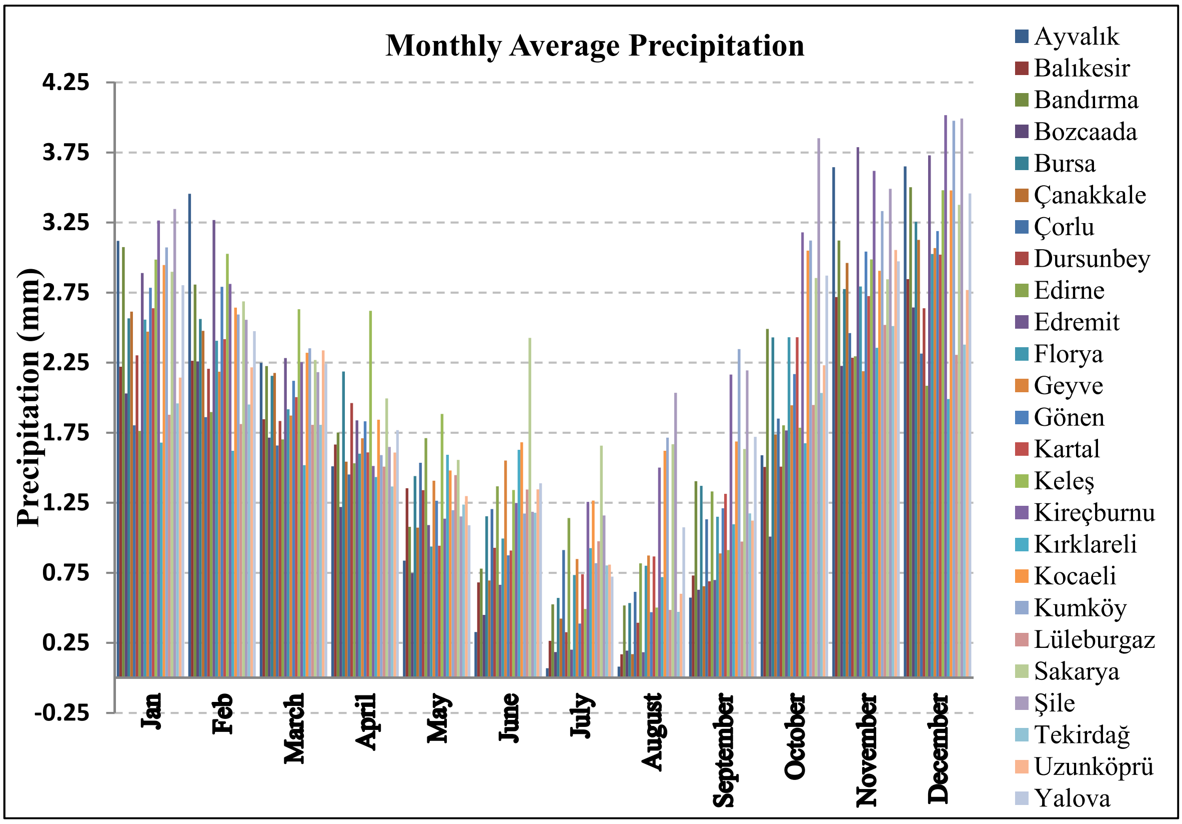


Figure 2. Climatology of monthly average precipitation based on the period of 1970-2010

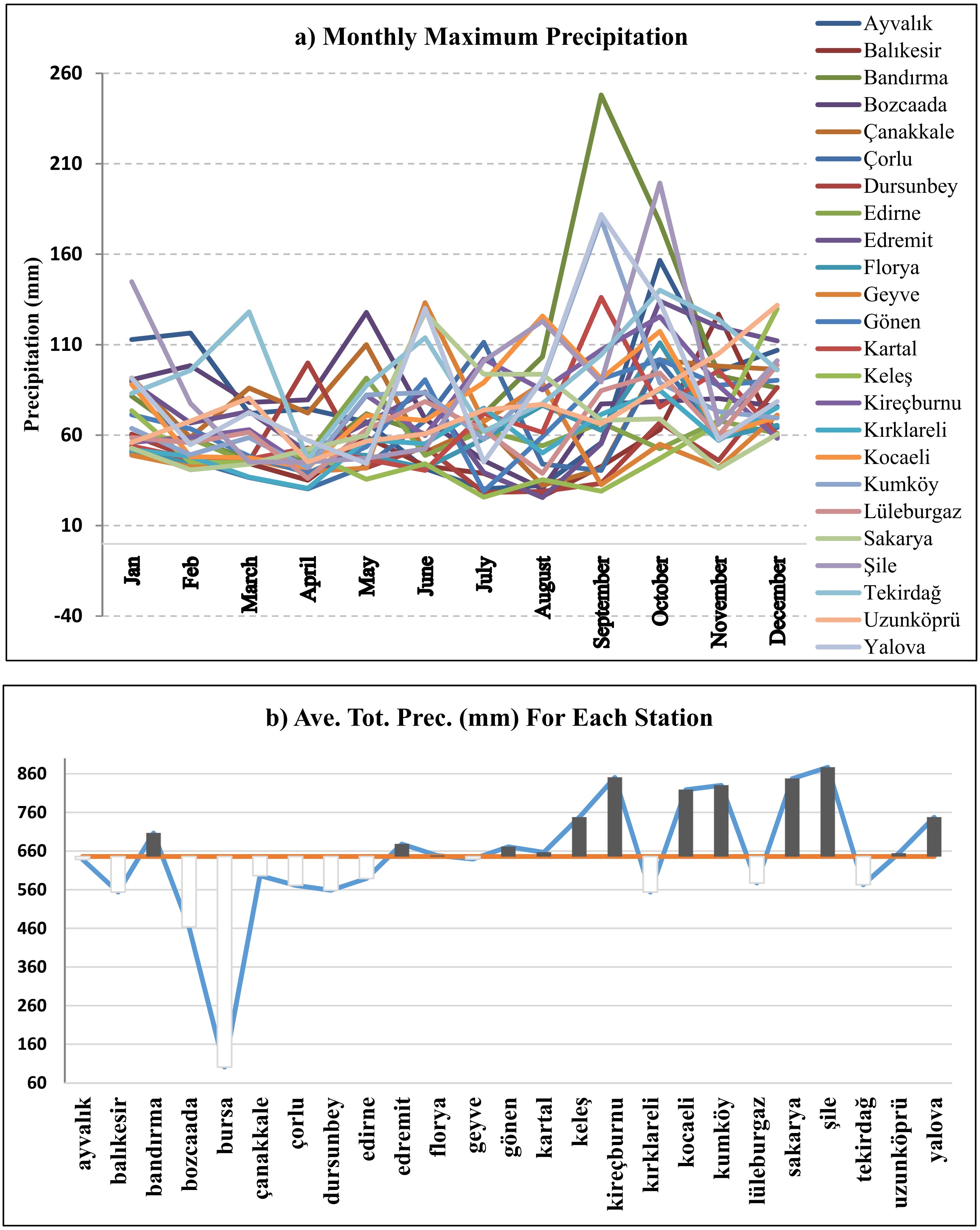


Figure 3. (a) Monthly maximum and, (b) average annual total precipitation (mm) observed by each station over 1970-2010

Figure 3 shows the amount of average annual total precipitation received by each station over 1970-2010. This is used as a safety assessment showing the reliability of the data. In this case the precipitation observed by Bursa station is around 100 mm per year which doesn't fit well with the mean value and standard deviation of the data which are 645mm and 104mm respectively. It is an error in either the precipitation data or in the observation equipment of the station. Another case for these lowest precipitation values of Bursa station could reveal the climate change impact on rainfall pattern.

Figure 4 is obtained by averaging the total amount of precipitation received by each station, every year. It is showing the increasing trend overall.

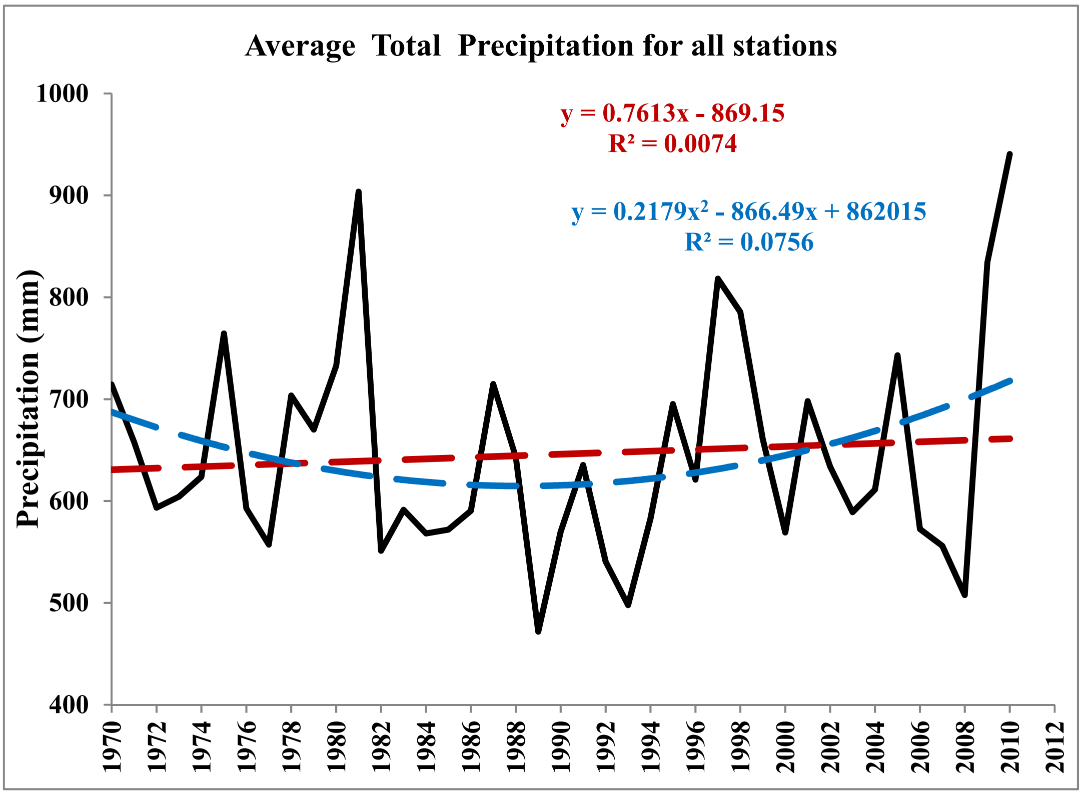


Figure 4. Average total precipitation observed by all stations and the trend line throughout 1970-2010

2.3 ERA-Interim Data

For the purpose of case study, 3 cases/dates were selected for the low-level jets and their effects on extreme weather events. The case study on these dates has been done by examining the wind velocity at 1000, 850 and 200 mb levels and surface data of 2m temperature, 2m dew point temperature, sea surface temperature (SST), mean sea level pressure (MSLP), evaporation, surface precipitation. The data has been acquired from ERA-Interim and consists of the years 1985, 1999 and 2009.

2.4 The Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO)

The AO and the NAO data used in this study begins from the January of 1950 and ends with February of 2014 and consists of monthly values. The data used in this study has been obtained from NCEP reanalysis. Due to the discontinuity of the precipitation data and the limited areal coverage of the temperature data, linear regression and principle component calculations were calculated for 8 stations only. The linear regression analysis used in this study to find the relationship between precipitation and Arctic and North Atlantic oscillations uses precipitation as the independent variable and Arctic and North Atlantic oscillations as the dependent variables.

The results of the linear regression analyses provide a correlation coefficient ranging between 0.00002 and 0.0054 (only selected stations are shown in Figure 5 and 6), which indicates a negligible linear correlation between precipitation-AO and precipitation-NAO. The minuscule correlation coefficient may be the result of the precipitation data comprises too much low values between 0.001mm and 1mm. Days with 0mm of precipitation were not included in these calculations.

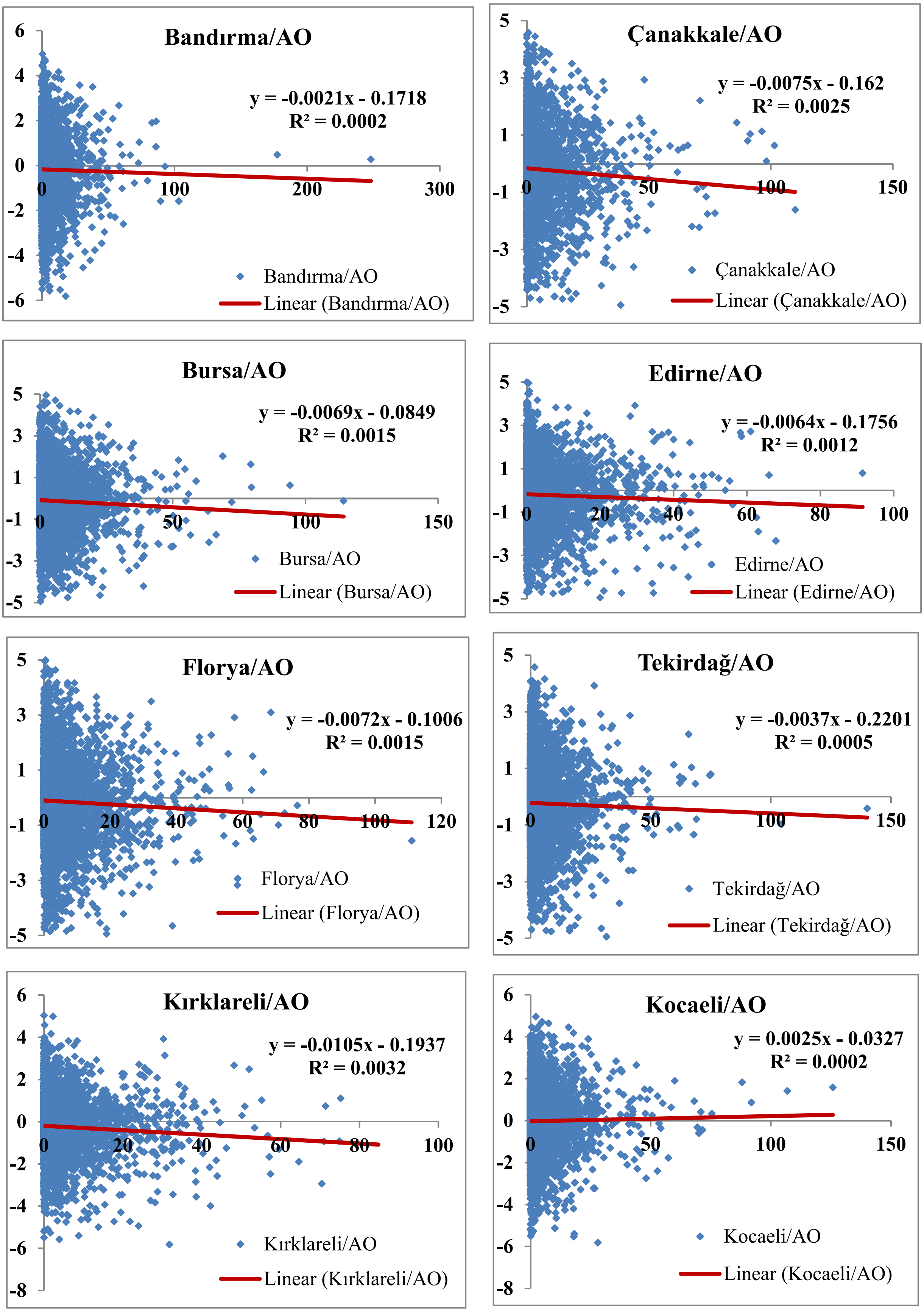


Figure 5. The Linear Regression Graphs for Precipitation data taken from 8 Meteorological Observation Stations and AO

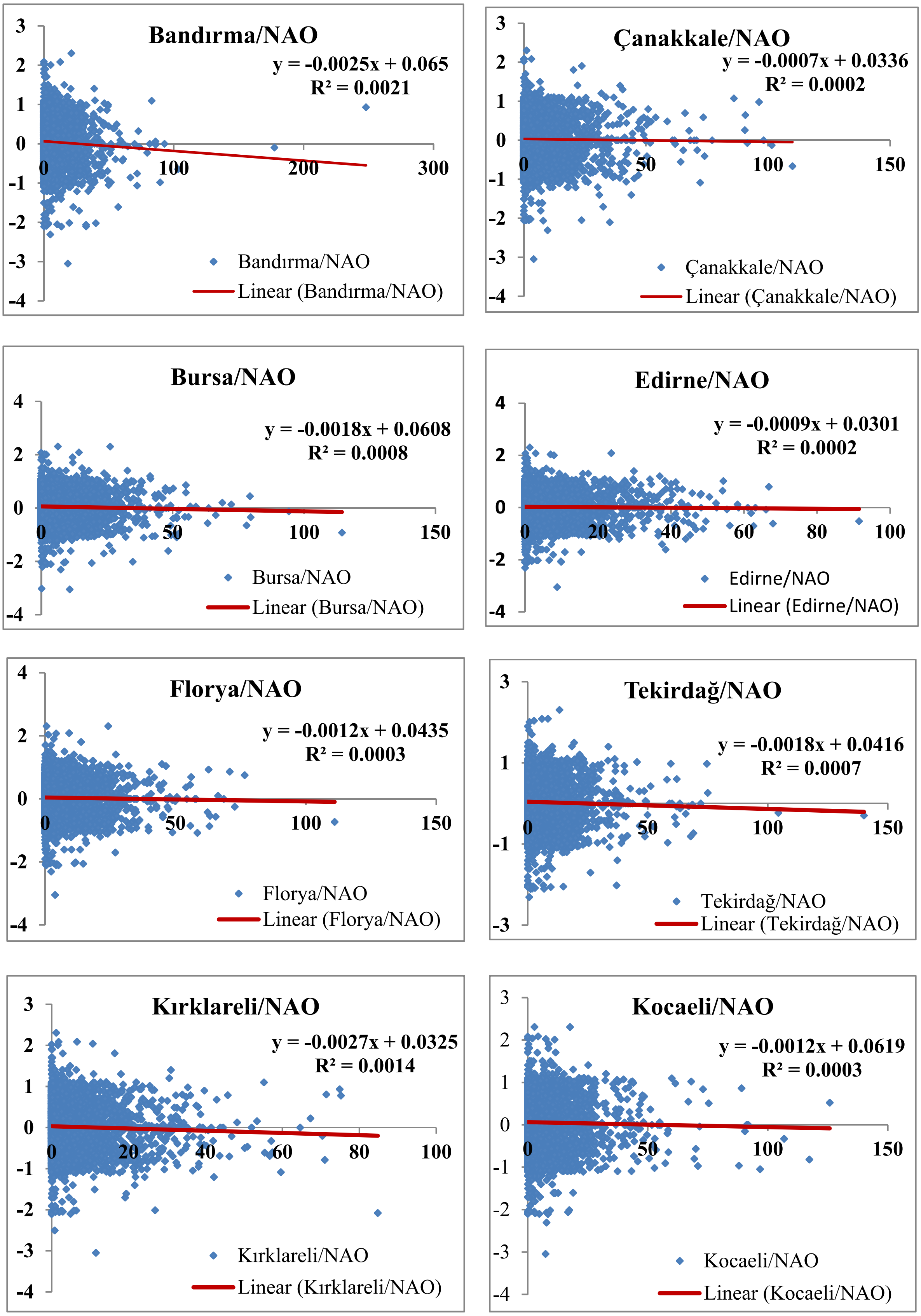


Figure 6. The Linear Regression Graphs for Precipitation data taken from 8 Meteorological Observation Stations and NAO

Table 1. Results of PCA for meteorological stations of Bandırma, Bursa, Edirne, Çanakkale, Florya, Kırklareli, Kocaeli and Tekirdağ.

```
Bandırma

      Prec.   AO   NAO Temp.
Prec.  1.00 0.00 -0.05 -0.06
AO     0.00 1.00  0.38  0.00
NAO   -0.05 0.38  1.00 -0.09
Temp. -0.06 0.00 -0.09  1.00

Standard deviations:
[1] 1.1815150 1.0307160 0.9703704 0.7746147

Rotation:
              PC1          PC2         PC3        PC4
Prec.  0.06605102 -0.707600675  0.69501210  0.1090721
AO    -0.68759208  0.075113799  0.24825277 -0.6781929
NAO   -0.70842344  0.004809511 -0.03837458  0.7047272
Temp.  0.14488140  0.702592392  0.67368846  0.1775308

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.182 1.031 0.970 0.775
Proportion of Variance 0.349 0.266 0.235 0.150
Cumulative Proportion  0.349 0.615 0.850 1.000
```

```
Bursa

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.04 -0.03 -0.09
AO    -0.04  1.00  0.38 -0.02
NAO   -0.03  0.38  1.00 -0.10
Temp. -0.09 -0.02 -0.10  1.00

Standard deviations:
[1] 1.1843328 1.0443919 0.9483922 0.7792007

Rotation:
              PC1         PC2         PC3         PC4
Prec.  0.07830035 -0.71428912 -0.69511435 -0.02182078
AO    -0.68424735  0.11611188 -0.21793109  0.68617027
NAO   -0.70219710 -0.01539596 -0.04096949 -0.71063612
Temp.  0.18053767  0.68997975 -0.68384470 -0.15391725

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.184 1.044 0.948 0.779
Proportion of Variance 0.351 0.273 0.225 0.152
Cumulative Proportion  0.351 0.623 0.848 1.000
```

```
Edirne

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.03 -0.01 -0.06
AO    -0.03  1.00  0.39  0.06
NAO   -0.01  0.39  1.00 -0.07
Temp. -0.06  0.06 -0.07  1.00

Standard deviations:
[1] 1.1786934 1.0332799 0.9743680 0.7704684

Rotation:
               PC1        PC2         PC3          PC4
Prec. -0.084700660 -0.6334758 -0.76909136  0.005715628
AO     0.704861487  0.0874210 -0.14451284  0.688944040
NAO    0.704201113 -0.1531668  0.04346218 -0.691918907
Temp. -0.009842515  0.7533962 -0.62106808 -0.215804697

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.179 1.033 0.974 0.770
Proportion of Variance 0.347 0.267 0.237 0.148
Cumulative Proportion  0.347 0.614 0.852 1.000
```

```
Çanakkale

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.04 -0.01 -0.09
AO    -0.04  1.00  0.38  0.00
NAO   -0.01  0.38  1.00 -0.09
Temp. -0.09  0.00 -0.09  1.00

Standard deviations:
[1] 1.1813632 1.0467354 0.9493654 0.7793788

Rotation:
             PC1         PC2         PC3         PC4
Prec.  0.0683581 -0.70455292 -0.70614896 -0.01691181
AO    -0.6891624  0.13196237 -0.18187953 -0.68888381
NAO   -0.7044381 -0.04395618 -0.04127263  0.70719965
Temp.  0.1554002  0.69588719 -0.68305934  0.15818264

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.181 1.047 0.949 0.779
Proportion of Variance 0.349 0.274 0.225 0.152
Cumulative Proportion  0.349 0.623 0.848 1.000
```

```
Florya

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.04 -0.02 -0.06
AO    -0.04  1.00  0.38  0.00
NAO   -0.02  0.38  1.00 -0.10
Temp. -0.06  0.00 -0.10  1.00

Standard deviations:
[1] 1.1827241 1.0314590 0.9658862 0.7773801

Rotation:
              PC1         PC2        PC3          PC4
Prec. -0.08119985  0.69903739 0.71044341  0.004844073
AO     0.68444675 -0.13426493 0.21499881 -0.683579616
NAO    0.70461321  0.04313535 0.03326668  0.707497624
Temp. -0.16869930 -0.70104136 0.66928245  0.179283452

Importance of components:
                        PC1   PC2   PC3   PC4
Standard deviation     1.18 1.031 0.966 0.777
Proportion of Variance 0.35 0.266 0.233 0.151
Cumulative Proportion  0.35 0.616 0.849 1.000
```

```
Kırklareli

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.06 -0.03 -0.01
AO    -0.06  1.00  0.39  0.02
NAO   -0.03  0.39  1.00 -0.08
Temp. -0.01  0.02 -0.08  1.00

Standard deviations:
[1] 1.1846487 1.0111072 0.9892289 0.7718134

Rotation:
             PC1        PC2        PC3         PC4
Prec.  0.1542988 -0.5204520 0.83899057 -0.03763546
AO    -0.6906083  0.1295493 0.17645241 -0.68930524
NAO   -0.6994522 -0.1232376 0.08354388  0.69899896
Temp.  0.1000935  0.8349606 0.50791712  0.18666093

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.185 1.011 0.989 0.772
Proportion of Variance 0.351 0.256 0.245 0.149
Cumulative Proportion  0.351 0.606 0.851 1.000
```

```
Kocaeli

      Prec.    AO   NAO Temp.
Prec.  1.00  0.00 -0.02 -0.05
AO     0.00  1.00  0.39 -0.03
NAO   -0.02  0.39  1.00 -0.10
Temp. -0.05 -0.03 -0.10  1.00

Standard deviations:
[1] 1.1872974 1.0200783 0.9725015 0.7771782

Rotation:
              PC1         PC2        PC3         PC4
Prec. -0.01210297 -0.76471220 0.64137895 -0.06084259
AO     0.67798644  0.12918453 0.23184649  0.68548738
NAO    0.69930392  0.06463622 0.02276392 -0.71153214
Temp. -0.22619005  0.62797195 0.73100072 -0.14187049

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.187 1.020 0.973 0.777
Proportion of Variance 0.352 0.260 0.236 0.151
Cumulative Proportion  0.352 0.613 0.849 1.000
```

```
Tekirdag

      Prec.    AO   NAO Temp.
Prec.  1.00 -0.02 -0.03 -0.05
AO    -0.02  1.00  0.38  0.02
NAO   -0.03  0.38  1.00 -0.09
Temp. -0.05  0.02 -0.09  1.00

Standard deviations:
[1] 1.1788126 1.0273793 0.9753661 0.7768872

Rotation:
              PC1         PC2         PC3         PC4
Prec.  0.06971922 -0.67502766  0.73265800  0.05185701
AO    -0.69234181  0.10147712  0.20775696 -0.68352195
NAO   -0.70903408 -0.04787393 -0.02639852  0.70305183
Temp.  0.11433598  0.72921063  0.64757426  0.18927948

Importance of components:
                         PC1   PC2   PC3   PC4
Standard deviation     1.179 1.027 0.975 0.777
Proportion of Variance 0.347 0.264 0.238 0.151
Cumulative Proportion  0.347 0.611 0.849 1.000
```

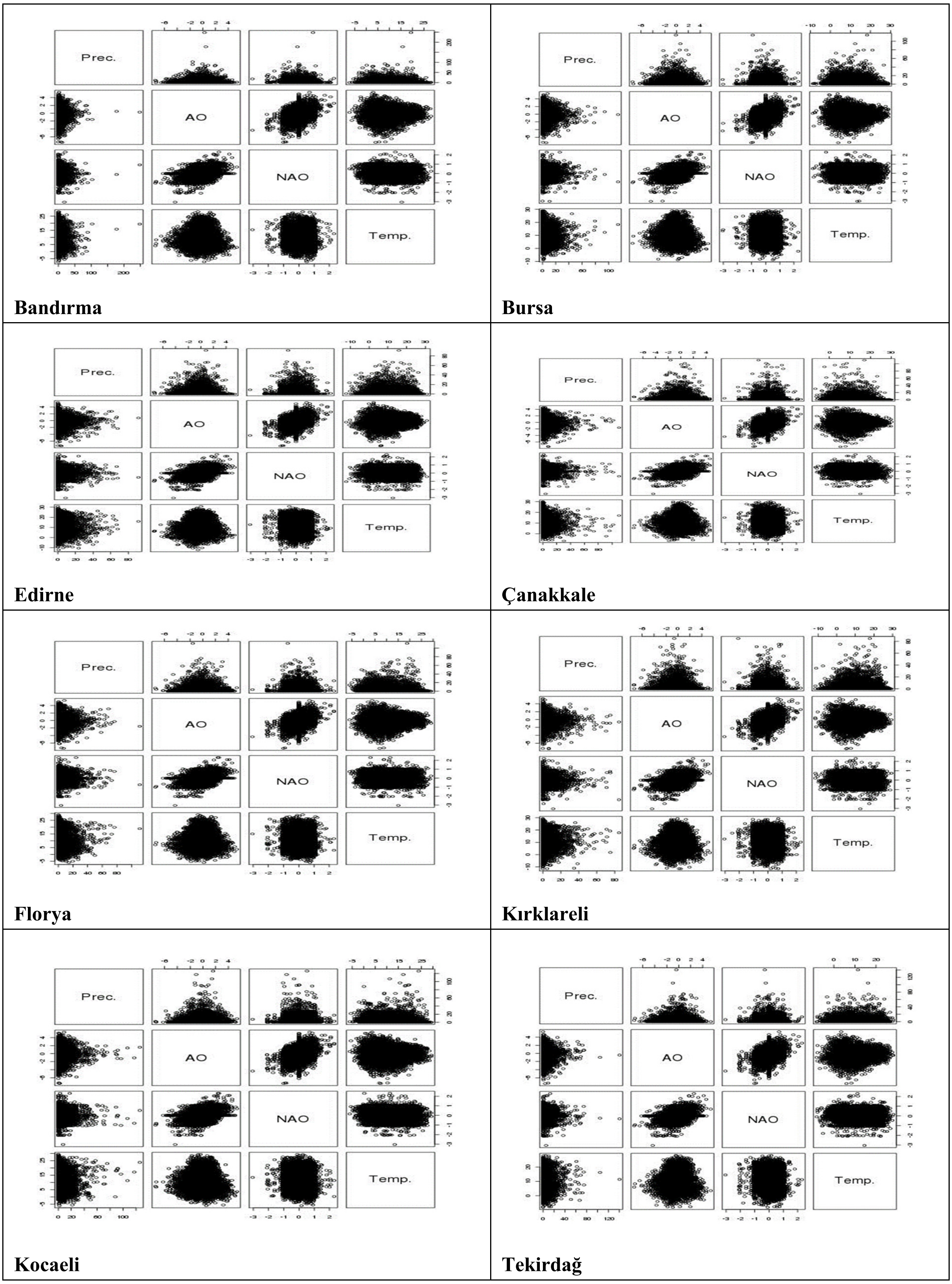


Figure 7. The Linear Regression Graphs for 8 stations. The variables are: Precipitation, AO, NAO, and Temperature

The following calculations have been made in the program R. The following graphics are the linear regression plots of precipitation, temperature, AO and NAO for each of the stations in Figure 7. PCA involves the analysis of correlation coefficients of the linear combinations of these variables and the components in terms of standard deviation, proportion of variances, cumulative proportion of variances. The results for the 8 stations considered in this study are as follows in Table 1.

According to these PCA Table 1 the highest value of the PCA-1 stands for precipitation. The high value of variance and standard deviation for precipitation, which are both important factors for PCA due to its assumptions of linearity and its assumption of large variances being more important dynamically.

3. Evaluation of Case Studies with ERA-Interim Data

3.1 The Selection of the Cases

The third section includes 3 case studies in order to examine the physical relationship between the low-level jets and extreme precipitation events. For the purpose of this study, the cases were selected primarily from the precipitation data by finding the days, those have the maximum precipitation between the years 1970-2010 for each station. The dates of these events were then compared with those ones indicate a pattern due to either the proximity of the stations or the events happening in relatively close time intervals indicate that multiple stations were affected by the same event. Somehow, in some extreme events no such relation could've been found. Such dates are mentioned in the Table 2.

Table 2. Extreme Weather Cases and Locations

Name of Stations	Number of Stations	Year	Month	Day	Amount of Precipitation (mm)
Kirecburnu	17061	1985	10	16	125.5
Sile	17610	1985	10	17	199.3
Florya	17636	1997	10	14	111.0
Tekirdag	17056	1997	10	16	140.1
Geyve	17662	1999	6	26	133.2
Sakarya	17069	1999	6	26	127.7
Bandırma	17114	2009	9	9	248.0
Kumkoy	17059	2009	9	13	179.4

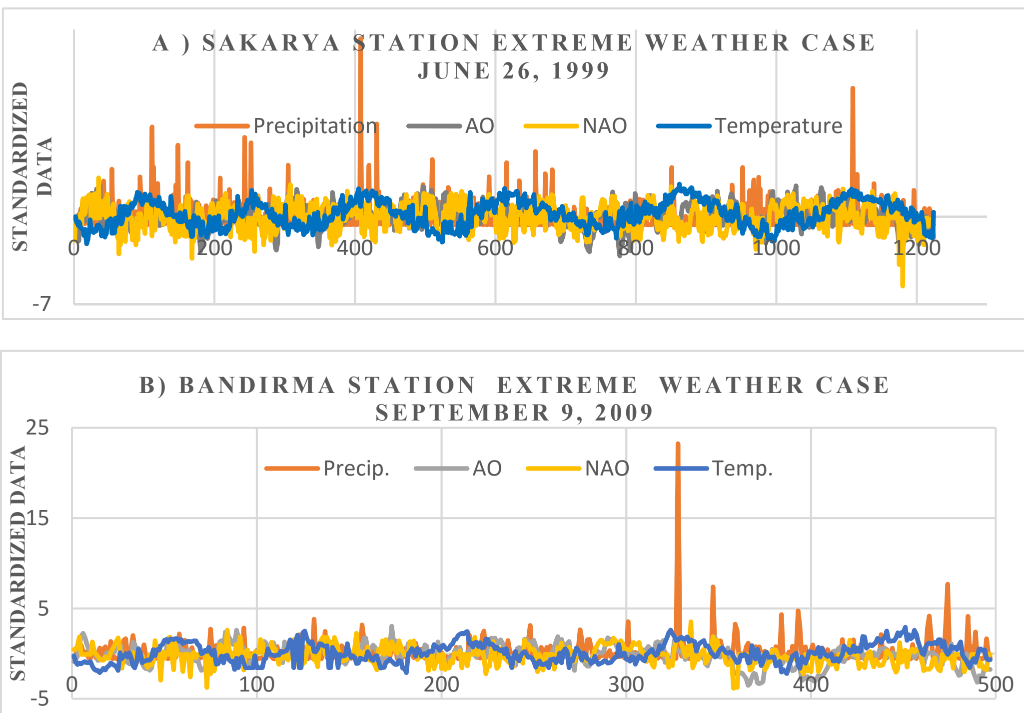


Figure 8. Standardized time series of two cases for precipitation, temperature, AO and NAO

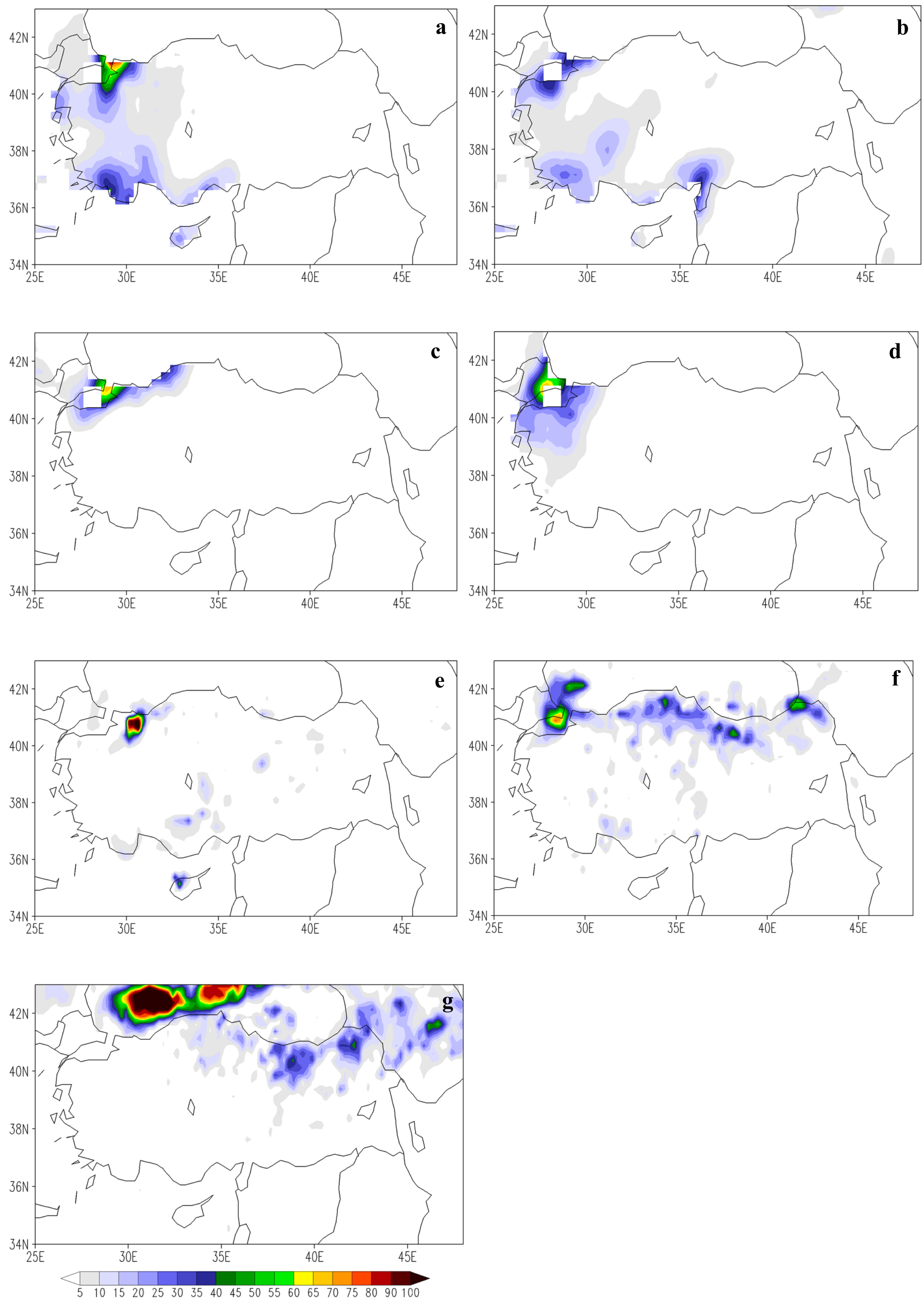


Figure 9. Daily precipitation from APHRODITE and TRMM3B42 in mm for (a) October 16, 1985 (b) October 17, 1985 (c) October 14, 1997 (d) October 16, 1997 (e) June 26, 1999 (f) September 09, 2009 and (g) September 13, 2009

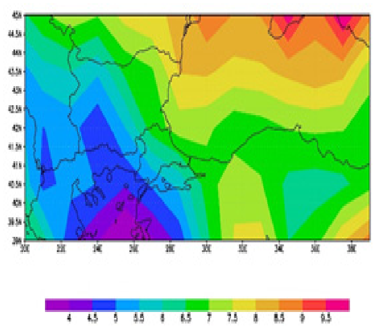
As a result, October 16, 1985; June 26, 1999 and September 11, 2009 were selected for this study, because of the severity of the amount of precipitation. Extreme heavy rain cases of 2009 and 1999 are chosen to relate the interconnection of precipitation with NAO, AO and temperature. Figure 8 displays the standardized time series of precipitation, AO, NAO and temperature for two cases, those were observed in Sakarya and Bandırma regions on June 26, 1999 and September 9, 2009. The precipitation and temperature data sets were standardized to make them dimensionless to relate with AO, NAO, and temperature. Daily precipitation and temperature were subtracted from the climatological values (average), and then divided by standard deviation.

Figure 9 shows the extreme rainfall cases listed in the Table 2 over Turkey and the adjacent areas. Each panel of figure display the spatial pattern of the rainfall distributions from APHRODITE for years 1985 and 1997; TRMM3B42 for years 1999 and 2009. The rainfall spots are matching with the geometrical stations locations, we considered in the Figure 1. The spatial pattern of rainfall shows a flow of rainfall from west to east. Most of the extreme rainfalls are occurring over northern part of the Turkey. Daily rainfall in Figure 9 (a) and (c) show the maximum rainfall of 100 mm. The centers of heavy rainfall on a particular day are matching with the location of the station in the Figure 1.

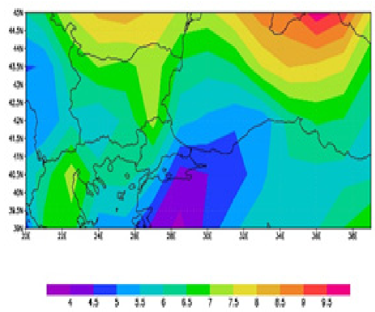
3.2 Surface Evaluation of Case Studies

Here, an attempt is being made to understand the surface conditions and better evaluation, if these events were somehow related to AO and NAO induced low-level jets a number of surface maps were created using the ERA-Interim datasets. The data considered from the 1st of January of each year (1985, 1999 and 2009) to 31st of December. The gridded data involves 2m Temperature, 2m Dew Point Temperature, MSL, SST, precipitation and evaporation parameters.

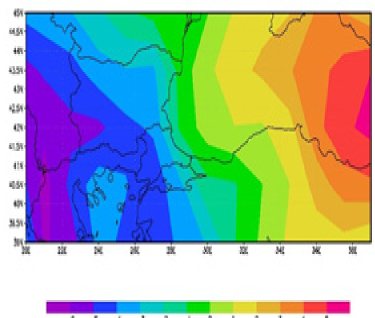
3.2.1 Surface Temperature Analysis



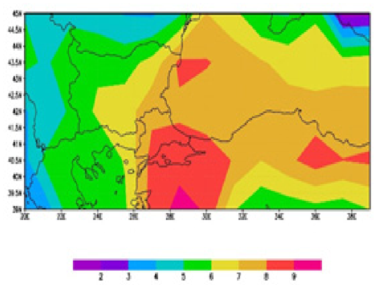
a) 2m Temperature 2009



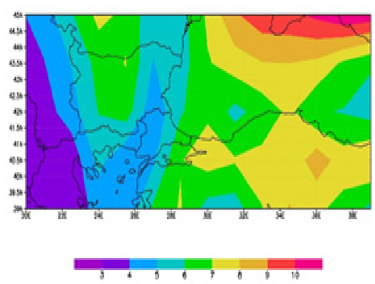
b) 2m Temperature 1999



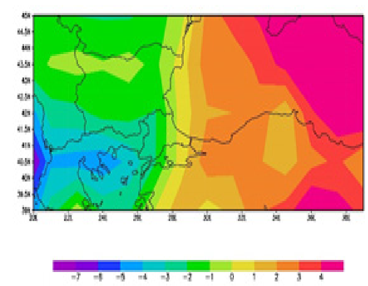
c) 2m Temperature 1985



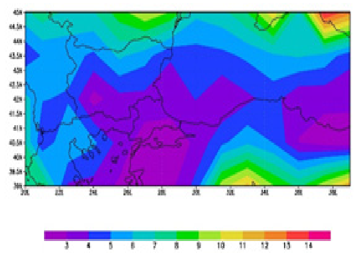
d) 2m Dew Point Temperature 2009



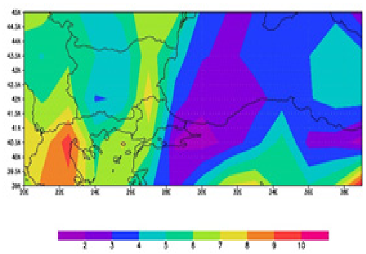
e) 2m Dew Point Temperature 1999



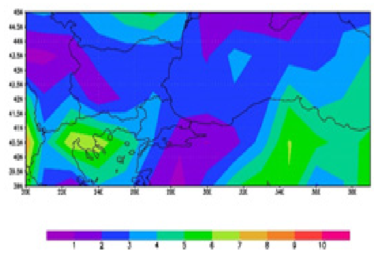
f) 2m Dew Point Temperature 1985



g) 2m Dew Point Depression 2009



h) 2m Dew Point Depression 1999



i) 2m Dew Point Depression 1985

Figure 10. Surface Temperature Maps of Extreme Cases

The three cases show different temperature patterns but each of these can be considered quite low for their relative months in Figure 10. The temperature map of June 26, 1999 (Figure 10b, 2m Temperature) is showing record low temperature of 4 to 5.5°C while the other two cases show temperature of 4 to 7°C (2009) and -5 to 0°C (1985). In each case there is a strong temperature gradient of about 1°C per longitude. The dew point temperature of 2009 case is ranging from 6 to 9°C, 4 to 8 °C (1999) and -4 to 2°C (1985). The dew point depression in each case is around 2°C which is below the average indicator of heavy rain which should be around 4°C.

3.2.2 Evaporation and Precipitation Anomalies

Anomaly maps of evaporation and precipitation are shown in Fig 11. The evaporation charts are exhibiting higher than average evaporation rates for both the cases in June (1999) and September (2009) while the case in October (1985), it is exhibiting a lower than average evaporation rate when compared with the total year. However, the evaporation rates in 1985 are still quite high in the study area when compared with its surrounding area (Figure 11).

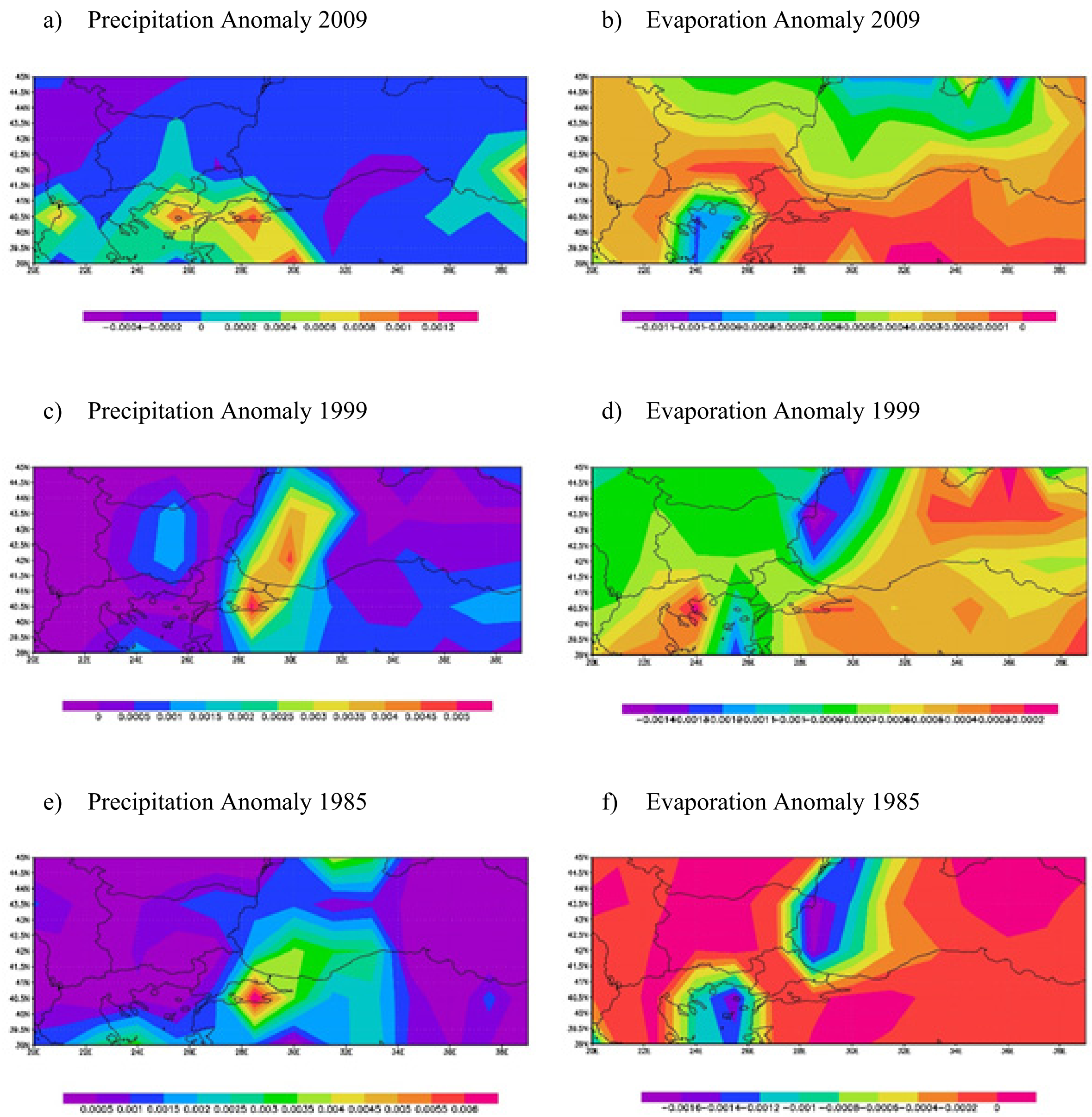
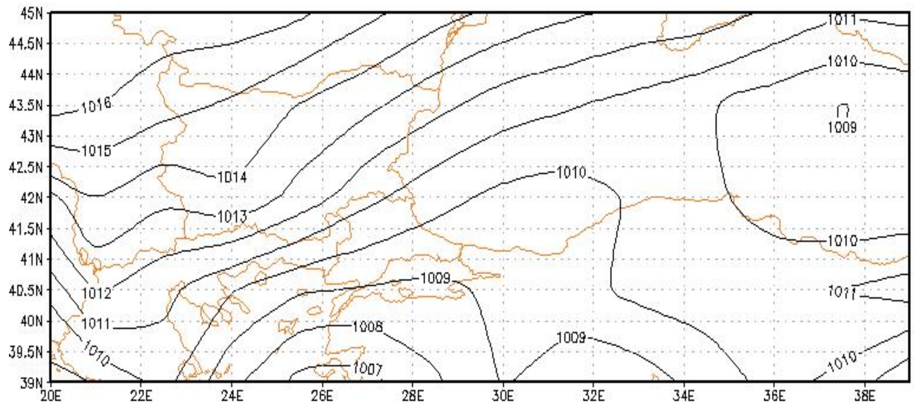


Figure 11. Evaporation and Precipitation Anomalies of the selected extreme cases (2009, 1999, and 1985)

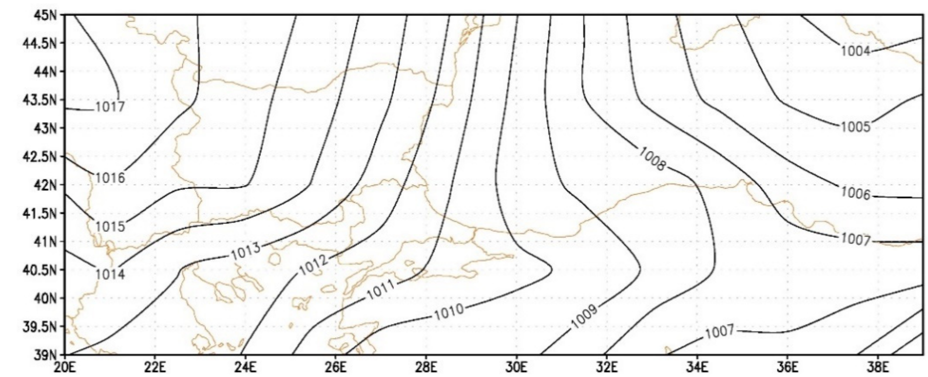
The values shown in the legends of these maps are in terms of dam so a factor of 10000 must be multiplied to get the usual term (mm) of precipitation and evaporation. In Figure 11a, precipitation anomaly chart of 2009 is indicating a relatively low anomaly with a range of 4 to 12 mm whereas both the cases of 1999 and 1985 are indicating a huge precipitation anomaly over the area with ranges of 5 to 50 mm and 5 to 60 mm respectively. However, every one of the charts are showing a condense area of precipitation surrounded by a larger area of low precipitation and no precipitation implying that this might have been a case of convective movement rather than a frontal precipitation.

3.2.3 Mean Sea Level Pressure Charts

a) Mean Sea Level Pressure 2009



b) Mean Sea Level Pressure 1999



c) Mean Sea Level Pressure 1985

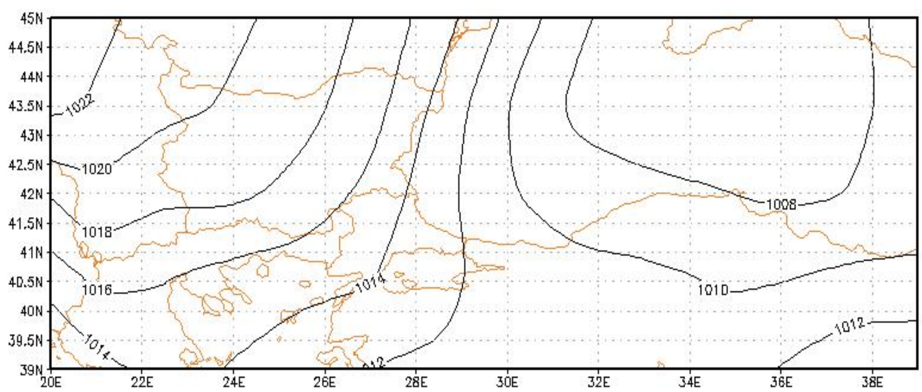


Figure 12. MSL of the 3 cases

The MSL charts are showing standard values for mean sea level pressure over the study area although there seems to be strong gradients over the area especially in the 1999 and 2009 cases. This implies that there are strong jet currents in the upper troposphere in Figure 12.

3.3 Wind Speed Anomalies at Pressure Levels

In the cases of both 1985 and 2009 strong wind speed gradients are present over the study area which indicates a rapid change in the wind velocity vectors (Figure 13).

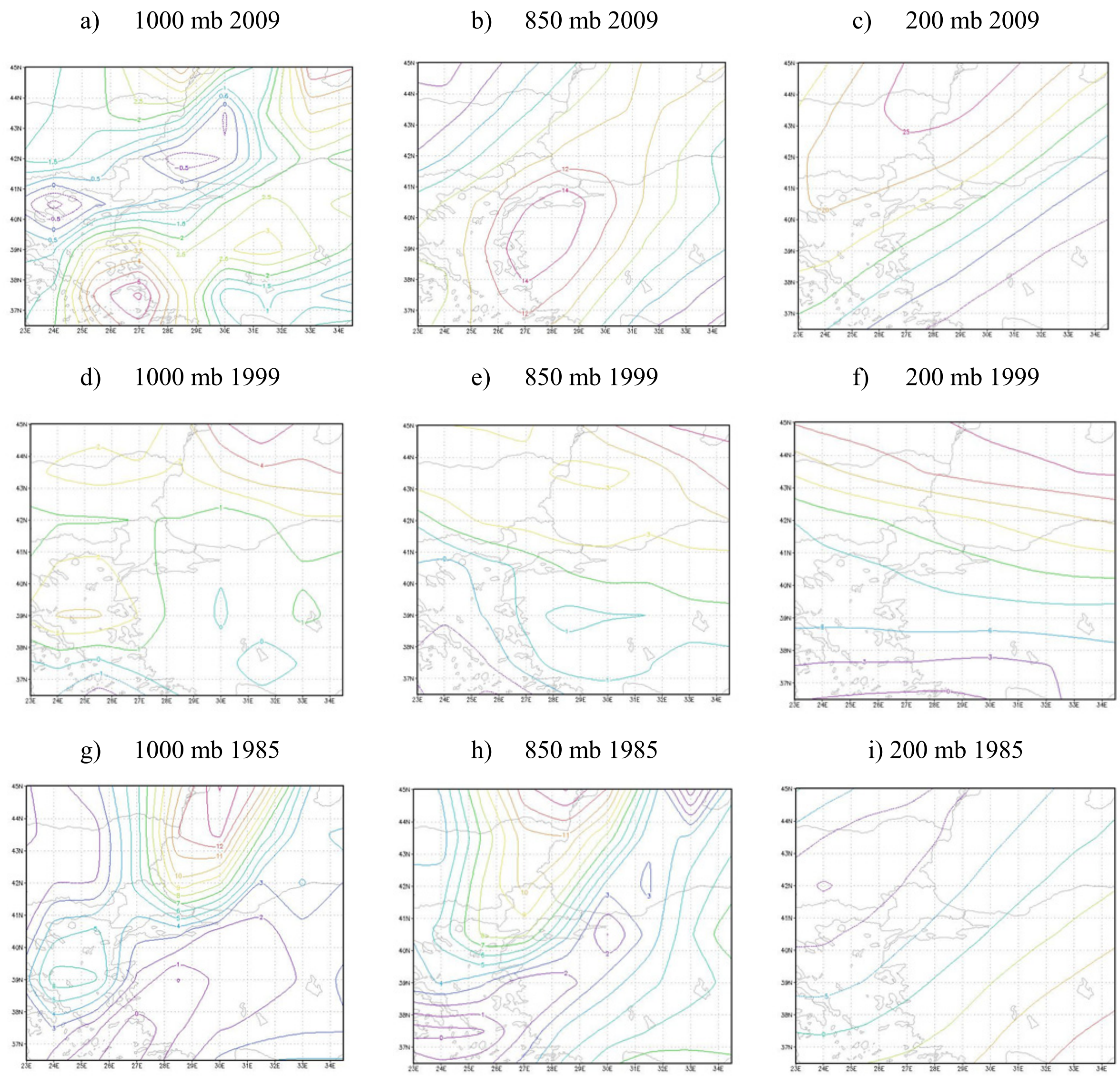


Figure 13. Wind speed anomaly of the cases at 1000, 850 and 200 mb

The general pattern observed in the 1000 mb wind speed anomalies continues to show itself in the 850 mb wind speed anomaly maps as well. A high gradient is persistent at this pressure level as well in the cases of 1985 and 2009 with 1985's gradient being stronger. The 1999 case is showing rapid change in wind speed, which is expected at this pressure level (Figure 13).

The 200 mb wind speed anomalies shows that the highest wind speed gradient was found in the case of 2009 in Figure 13c. Since the winds blowing at this level are already at high speed conditions, but in the 1999 and 1985 cases it is not necessarily indication of a high-level jet pattern with a change rate of 3 and 5 m/h respectively. Although the change rate between the contours in cases of 1985 and 2009 are the same, the density and the high values of the 2009 case indicates a 200mb jet stream (Figure 13).

4. Conclusion and Discussions

Extreme weather events are rare elements of a climate. They are generally not expected, except as an anomaly in the probability density function. They depend on many factors including local effects from meso- to synoptic-scale climates and remote effects from the tele-connection patterns (ENSO, AO, NAO) and air mass movements. In this study the precipitation regime of the local climate has been examined statistically for a 40-year period. The study includes observational data taken from 23 meteorological observation stations in the Marmara region.

The linear regression analysis of the precipitation data from the stations and AO and NAO data do not show any significant sign of linear relationship between these three variables. PCA is been done using 8 meteorological stations (Bandırma, Bursa, Çanakkale, Edirne, Florya, Kırklareli, Kocaeli, Tekirdağ) between the precipitation, temperature and AO, NAO data. The results of the PCA don't show a well-established linear relationship between these variables but the analysis shows a significant correlation coefficient of temperature-precipitation and AO-NAO pairs.

With the help of these analyses 3 cases of extreme weather events have been identified and cross-checked. Since a linear correlation between the precipitation regime and the AO and NAO found to be almost zero; it was a curiosity if low-level jets have any relationship with extreme precipitation events. The examination of these parameters have shown higher than normal wind speeds at 1000 mb and 850 mb for the cases of 2009 and 1985 and extremely higher than normal wind speed at 200 mb for the case of 2009.

Sirdas et al. (2013) have revealed very significant results in their research related with global warming effects on extreme weather events. The study advised, which is quoted here; "The average daily sunning time in July and August is 11-12 hours where evaporation is also visibly higher. In winter times, however, this declines to 3-4 hours and for this reason, it ends without causing evaporation of the water. In general, it has been found out that regions such as the Mediterranean region are more sensitive and vulnerable to climate change. As a country in the aforementioned region, Turkey needs to be prepared for inevitable severe weather and extreme climate conditions".

To sum up, linear regression analysis and/or principle component analysis of the parameters used in this study are too simple to express the linear relationship between teleconnection patterns, low-level jets and extreme precipitation. The examination of the cases shows that there is a physical relationship between low-level jets and extreme precipitation events; the relationship between teleconnection patterns and low-level jets has been established. The possibility exists that if there is a relationship between these three concepts it is more complex than a linear relationship and/or involves more physical parameters.

Acknowledgement

We would like to thank NCEP, ECMWF and Turkish State Meteorological Services (MGM) for letting us use their data.

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