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Variability of 850 hPa summer temperatures over Turkey in the period of 1963-2000

Zahide Acar Deniz *

The Physical Geography Division, Department of Geography, Çanakkale Onsekiz Mart University, Çanakkale, Turkey

Abstract

Study area is located between 25°-60°N latitude and 25°W-50°E longitude. In this study, monthly reanalysis data of 850 hPa level air temperature values are used at grid points spaced by 2.5°x2.5° in latitude and longitude for the period of 1963-2000. The main evaluation of the present study may be summarized as follows: 1) Long-term averages of 850 hPa level temperatures over the Mediterranean basin are controlled by three dominant systems in summer. These consist of the Azores high pressure and the northeast Atlantic originated mid-latitude depressions and northwestern extension of the monsoon circulation. 2) An intensified and spatially coherent tropical circulation is effective in the Mediterranean basin, whereas the northern Atlantic and European originated frontal depressions influence the Western Europe and its surroundings.

Keywords: Extreme Temperatures; Principle Component Analysis (PCA); Atmospheric Circulation; 850 hPa Level; Turkey

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* Corresponding author. *E-mail address:* zdeniz@comu.edu.tr

1. Introduction

Numbers of studies have analyzed extreme temperatures (e.g. heat waves), flood and flashflood events, influence of extreme events on human life and quality of life. Variability and trends of precipitation and air temperatures have been examined regionally by many researchers for the Mediterranean basin (e.g. Alpert et al., 2006; Xoplaki et al., 2003; Feidas et al., 2007; Ben-Gai et al., 1999, Rodo et al., 1997; Esteban Parra et al., 1998; Delitala et al., 2000; etc.).

Studies dealing with the extreme air temperatures indicated that changes in air temperature extremes are consistent with warming of the climate (IPCC, 2007). A widespread reduction in number of frost days in mid-latitude regions, an increase in the number of warm extremes and a reduction in number of daily cold extremes were observed in about 70-75% of the land surface areas, in where observational data are available. The most marked changes were found in cold nights (lowest 10% based on 1961–1990 normal period) and warm nights (highest 10%) become more frequent (Trenberth et al., 2007). Cold days, cold nights and frosts days have become less frequent over most land areas, while hot days and hot nights have become more frequent in many European and the Mediterranean countries including Greece, Turkey, Eastern Mediterranean region (e.g. Black et al., 2004; Feudale and Shukla, 2010; Kuglitsch et al., 2010; Kostopoulou and Jones, 2005; Sanchez-Lorenzo et al., 2011; Tolika et al., 2011; etc.).

Sanchez-Lorenzo et al. (2011) detected a significant increasing trend in frequency of tropical nights in Iberian Peninsula during summer months from June to September for the period 1961-2007. Della-Marta et al. (2007) indicated the existence of two circulation patterns responsible for the occurrence of heat waves in the Europe. One with anomalously high sea level pressure (SLP) values centered over the Scandinavia and anomalously low SLP over south of Greenland, the Mediterranean and North Africa, resulting anomalously high frequency of heat waves in the northern and Western Europe. The other pattern showed a distinct wave pattern with anomalously low SLP in the central North Atlantic and northeast Europe, and anomalously high SLP over central and Western Europe. They (2007) demonstrate that the Azores high increase in strength during summer time, and average SLP over some parts of Europe increase significantly and the summer Icelandic low deepens.

Nastos et al. (2011) analyzed time series of surface air surface temperatures (mean, minimum, maximum) using data sets of 26 Greek meteorological stations and NCEP/NCAR reanalysis gridded data. They (2011) found statistically significant positive trends in summer mean maximum and minimum air temperature over most area of Greece, while insignificant trends appear in winter, with the exception of the northern area presenting statistically significant negative trends.

The Mediterranean basin marks a transitional zone between the deserts of North Africa situated within the arid zone of the subtropical high and western, central and southern Europe affected mainly by westerly flows and mid-latitude cyclones particularly during the cool/cold months of the year (e.g. Xoplaki, 2002; Kuglitsch et al., 2010). On the other hand, the linkage between the Asian monsoon and the Eastern Mediterranean (EM) summer regime and particularly the mid-level atmospheric subsidence were shown by Rodwell and Hoskins (1996). They (1996) pointed out a strong association between the Asian Monsoon and this subsidence pattern, and attributed persistence of the EM subsidence, along with the lack of precipitation in summer, to period of persistence of the Asian Monsoon over the EM region.

Summer heat waves have significantly increased in frequency at most stations since 1880 and are likely to continue to increase (Della-Mart et al., 2007; Beniston, 2004; Meehl and Tebaldi, 2004; Schär et al., 2004) due to anthropogenic influences on climate. Della-Mart et al. (2007) revealed increases in average frequency of heat waves with a rate of 0.24 per decade since 1880 over the Western Europe. According to Kuglitsch et al. (2010), the temperature of hot summer days and nights (expressed as the seasonal daily maximum and daily minimum air temperatures with their 95th percentile) and the number, length and intensity of heat waves in the EM region have significantly increased since the 1960s. They identified "hot spots" of heat wave change across the western Balkans, southwestern and western Turkey, and along the Turkish Black Sea coastline.

As for the warm summer of the year 2010, Barriopedro et al. (2011) have recently shown that the 2010 summer was exceptionally warm in the Eastern Europe and large parts of Russia. They provided evidence that the anomalous 2010 warmth that caused adverse impacts exceeded amplitude and spatial extent of the previous hottest summer of 2003. In a recent preliminary study performed for the 2010 summer warmth and heat-waves over Turkey, Eastern European and Russia, Acar Deniz and Türkeş (2011) found that daily maximum air temperatures in Turkey were also corresponded to an anomalous warm period (heat-wave conditions) particularly in the 32th and 33th weeks (09.08.2010 - 22.08.2010) of the 2010 year. The significant warmth of the 32th and 33th weeks were effective in all of Turkey, while increases in number of tropical days over the Black Sea Region of Turkey were most remarkable during the 2010 summer.

This paper investigates interannual variability of the 850 hPa summer temperatures over the Mediterranean basin, Europe, Middle East and Turkey in comparison with the period of 1963-2000. The tropical, subtropical and mid-latitude originated pressure and circulation systems including northern Atlantic originated frontal cyclones, Azores subtropical high pressure, the descending branch of the Hadley cell and intertropical convergence zone and the Asiatic monsoon low pressure have been playing an important role on summer air temperature conditions and its variability. However, climatology, long-term variability of the summer 850 hPa temperatures and influence of large-scale circulations on summer climate in Turkey and surrounding regions have not been examined yet.

Therefore, in the first step of this study has been determined 850 hPa level temperature variability during the period 1963-2000. The data used has been described in the section two of the study, and the performed methodology has been explained in the section three. Results of the analysis, main findings and discussion, and conclusions have been given in sections four and five, respectively.

2. Data and methods

In this study, monthly 850 hPa geopotential level temperature data sets have been used for the period 1963-2000. The study area with these data sets is located over a large geographical region between 25°W-60°E and 25°-50°N. The monthly 850 hPa temperature data related to a grid point are averaged over a 2.5° x 2.5° latitude and longitude for the period of 1963-2000. The 850 hPa temperature data are taken from the

National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis 1 data archive (Kalnay et al., 1996). The gridded data of the NCEP/NCAR Reanalysis 1 project has been used widely by various researchers including climate and climate change scientists for state of the art analysis/forecast system to perform data assimilation using past data from 1948 to the present. The dataset is kept current using near real-time climate and atmospheric observations.

Principle Component Analysis (PCA) is known statistical technique for a data transformation. This advantageous technique is frequently used climate research. The eigenvector techniques have been used with increasing frequency since 1980s, and many studies related with EOF, PCA and common factor analysis (CFA) were published in climatological and meteorological literatures (Richman, 1986). Firstly, correlations matrix was computed from temperature data the geopotantiel level of 850 hPa. The eigenvalues and eigenvectors were derived from the correlation matrix and to produce component loadings of matrix. The first three components accounts for important of total variance (approximately 50%). Further details can be found in Preisendorfer (1988), Wilks (1995), Daultrey, 1976, Brunet et al. (2007), etc. Figure 1 shown 850 hPa geopotential level temperature data in the grid points.

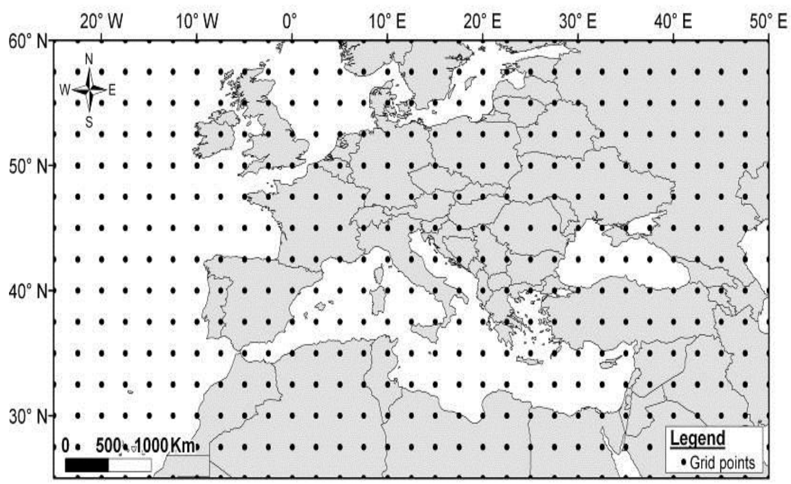

Figure 1. The geographical distribution of grid points (2.5°x2.5°) that provides 850 hPa temperature data used in this study.

3. Results

In this section is displayed the principle component analysis (PCA) for assessment long-term 850 hPa temperature conditions. The first six PC values of long-term monthly 850 hPa level air temperature series are given in Table 1. The first six principal components explain the cumulative variance of 76% in June, 79% in July, 81% in August and 77% in September (Table 1). In the study is used only the first three PCs to display the geographical distribution of the loads over the study area (Figure 2a, 2b, 3c).

Table 1: Eigenvalues, percentage explained variances and percentages of cumulative variances of the non-rotated first six principal components (PCs) for the monthly variations of 850 hPa geopotential level temperatures of the study area for the period 1963-2000.

PC	Eigenvalue	Explained variance (%)	Cumulative variance (%)
		June	
1	69.89	25.74	25.74
2	55.39	20.40	46.13
3	30.33	11.17	57.30
4	19.88	7.32	64.62
5	16.94	6.24	70.86
6	14.51	5.34	76.21
		July	
1	54.73	20.47	20.47
2	50.39	18.85	39.32
3	40.49	15.14	54.46
4	28.32	10.59	65.05
5	21.54	8.06	73.11
6	16.31	6.10	79.21
		August	
1	56.40	22.75	22.75
2	42.30	17.06	39.81
3	31.01	12.51	52.32
4	29.14	11.75	64.07
5	20.31	8.19	72.27
6	13.53	5.46	77.72
		September	
1	82.46	27.81	27.81
2	61.67	20.80	48.62
3	33.73	11.38	59.99
4	31.62	10.66	70.66
5	20.57	6.94	77.60
6	12.42	4.19	81.78

The first three PCs are responsible for more than 55% of the summer seasonal year to year variability of 850 hPa temperature (PC1: 25.7%, PC2: 20.4%, PC3: 11.2%). Negative values replace over the Mediterranean basin and Eastern Europe. PC values increased to Russia via the Aegean Sea. Negative values are seen over an area extending from Western Europe to England, whereas positive values display in the Mediterranean basin into Eastern Europe in June. There are two significant loading patterns. The first of the pattern represents the northeast Atlantic originated weather systems that dominate over the Western Europe. The other pattern is located over the Eastern Europe, which has shaped with both dynamical and thermal atmospheric conditions and mechanisms, and due partly to the summer monsoon circulation. Influences of the synoptic scale thermal atmospheric mechanisms and the monsoon circulation control the distribution and variations of the pressure and circulation conditions dominated over the Caucasus, Turkey, Mesopotamia and the Eastern Mediterranean basin at the 850 hPa level temperature in June.

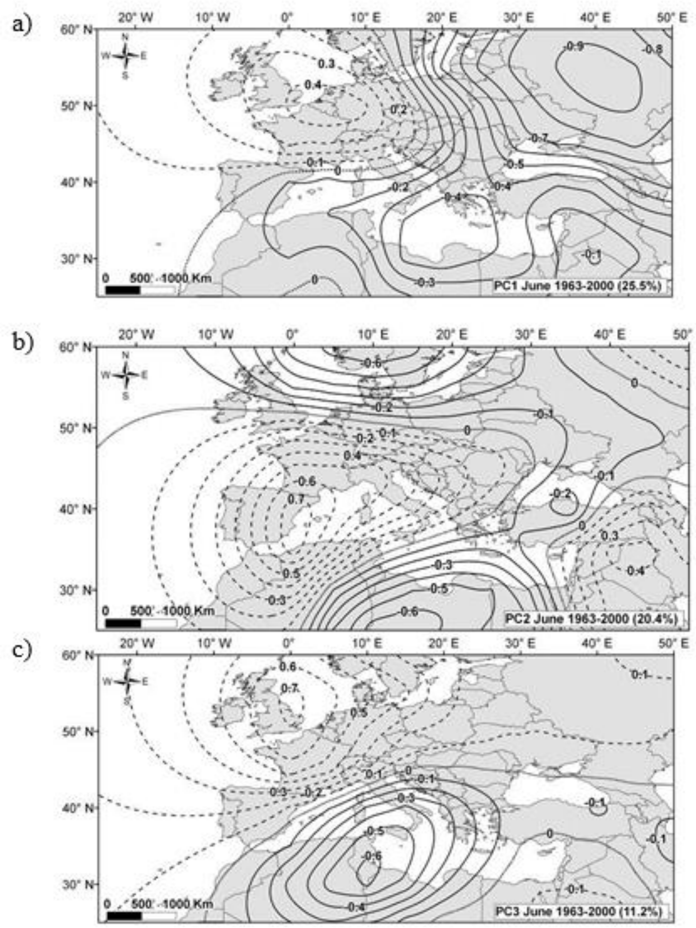

Figure 2. Geographical distribution patterns for loadings of the first principal component (PC) computed for June 850 hPa level air temperatures. PC1 map displays the loading patterns the monthly temperature series (1963-2000). In the PC map, dotted contours display zero values, dashed and straight contours display the positive and negative loadings, respectively. a)PC1, b) PC2, c) PC3, respectively

The second component accounts for 20.4% of the variance in the June 850 hPa level temperature (Table 1). Spain, Portugal, central and northern parts of Italy and the Middle East regions have relatively similar synoptic circulation conditions for 850 hPa level temperature in June.

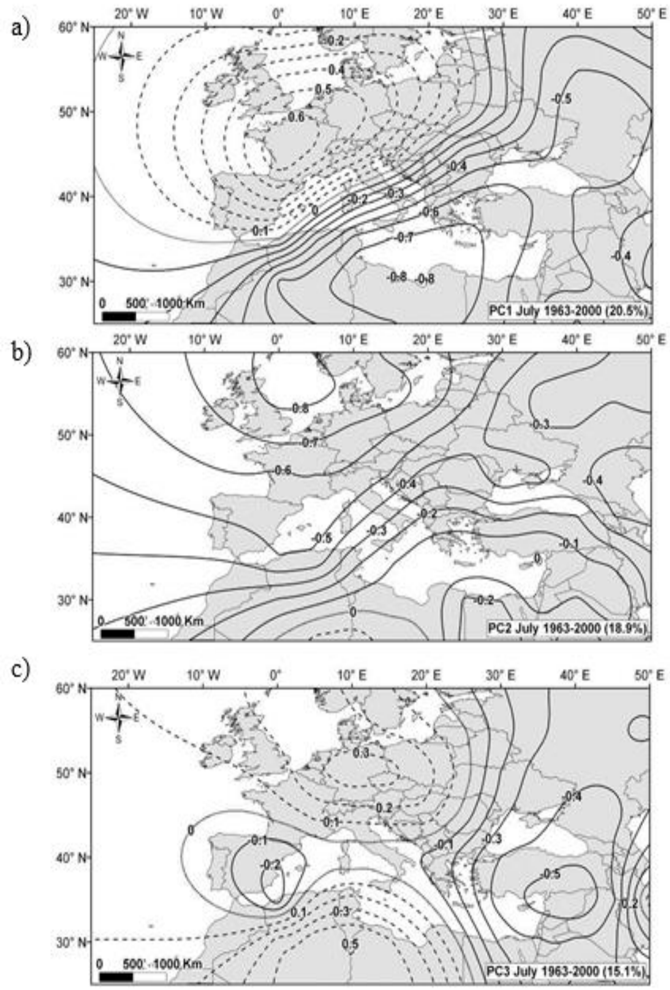

Figure 3. As in Figure 2 but for 1963-2000 july 850 hPa temperature a) PC1, b) PC2, c) PC3, respectively.

Geographical distribution of PC2 loadings represents dominant pressure patterns over the 850 hPa level summer temperature in the Mediterranean Basin and its surrounding regions. 850 hPa level temperatures in June have been influenced with a branch of Hadley as part of the ITCZ over the Northern Africa, the Azores high pressure over the Western Europe, northwest extension of the monsoon circulation over the Middle East and Turkey, and polar air masses originated from Arctic and North Atlantic regions (Figure 3a).

The third component (PC3) explained about 11.2% of the variance of 850 hPa level temperatures in June (Table 1). PC3 loading shows the geographical distribution of the maritime and continental air masses sourcing and influencing regions. Negative values dominate over the Western Europe, which have been affected by the maritime polar and maritime tropical air masses. Positive values have replaced over the

North Africa and its surroundings. Influencing continental air masses circulated over the Europe (Figure 3b, 3c).

The first three principal components describe year to year variability of July temperatures at 850 hPa geopotential level by the variances of 20.5%, 18.8% and 15.1%, respectively (Table 1). According to the PC1, positive values are observed to be centered over France and the Western Europe, while negative values are observed in the large regions from the Northern Africa to Turkey and Black Sea shores of the Russia. The loading patterns over the Western Europe and its surroundings are very likely controlled by the cyclonic North Atlantic circulations and the Azores high pressure, whereas the Mediterranean Basin except its western part is controlled mainly by tropical circulation in July (Figure 4a).

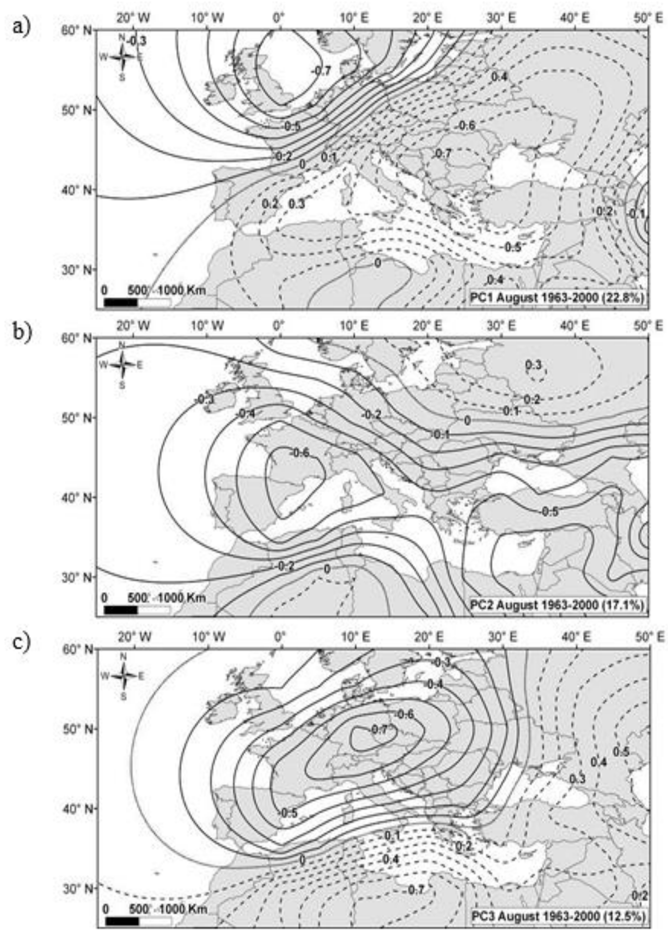

Figure 4. As in Figure 2 but for 1963-2000 August 850 hPa temperature a) PC1, b) PC2, c) PC3, respectively.

The loading of second component (PC2) displays a strong negative value pattern over all of the study area in July (Figure 4b). Northern Atlantic originated maritime polar and maritime tropical air masses have a dominant weather and circulation characteristics for the Western Europe and its surrounding regions in July (Figure 4b). the third component (PC3) loadings have positive values over the Northern Africa and the Northern Europe (Figure 4c). The Northern Africa controlled by the monsoon trough. The positive loadings over this area explain shifting of the monsoon trough toward the Mediterranean basin. Maritime polar and maritime tropical originated air masses are dominated over the Western Europe. The loading center over Turkey, Syria and Cyprus is the influence of continental origin air masses (Figure 4c).

In August, the first six PC eigenvalues clarify more than 70% of year to year variability for 850 hPa level air temperatures. Eigenvalues of PC1 explain 22.7% in year to year variations of the August temperatures (Table 1). Figure 6a indicates evident spatial relationships among the grid points that are characterized with negative values over the Northern Europe and positive values in Balkans, Turkey, Eastern Europe, Black Sea Basin and Middle East.

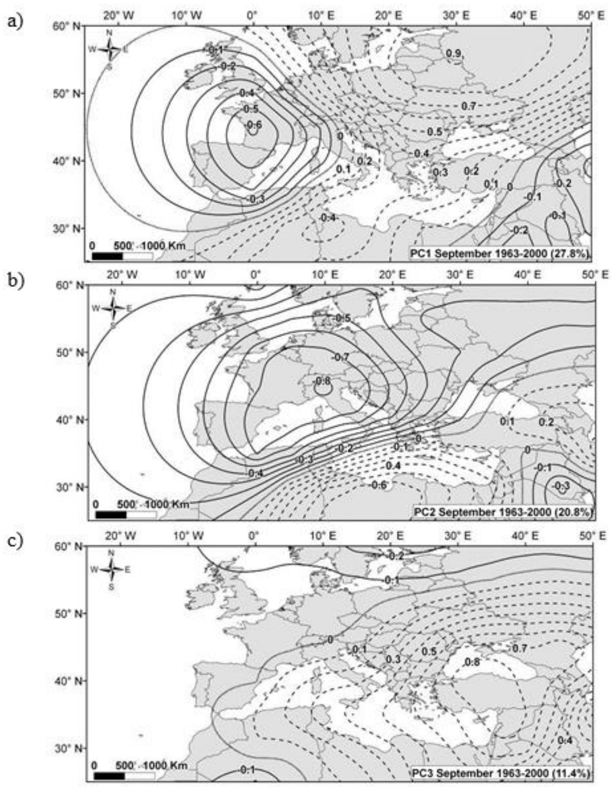

Figure 5. As in Figure 2, but for September 850 hPa level air temperatures: a) PC1, b) PC2, c) PC3, respective

Pattern in the figure 6a show the status of large-scale atmospheric circulation conditions in August. Accordingly, the 850 hPa temperatures are characterized by the effect of the northwest extension of the monsoon low pressure and thermal conditions. Especially, Turkey, Greece, Bulgaria, the Balkans, northern the Black Sea countries are characterized by the thermal conditions during the August. Northeastern Atlantic circulation is affected over the northern Europe, northern France and England (Figure 5a). The map of figure 6b explains only 17.1% of the year to year variance in the 850 hPa August temperatures. Negative values are exhibited over the investigated area expect for north of Russia in the 850 hPa temperature in August. According to spatial patterns very likely are effective also the ITCZ and the branch of Hadley over the southern Europe, Turkey and the Middle East (Figure 5b).

The eigenvalue of PC3 accounts for 12.5% of the 850 hPa in August temperatures in the figure 6c. The occurrence and domains area of maritime and continental air masses have indicated by the spatial distribution of the PC3 loading map. From the Atlantic Maritime air masses is dominated over the Central Europe, while over the northern Africa, the Middle East, Turkey, the Caucasus and Eastern Europe is dominated by the continental air masses (Figure 5c).

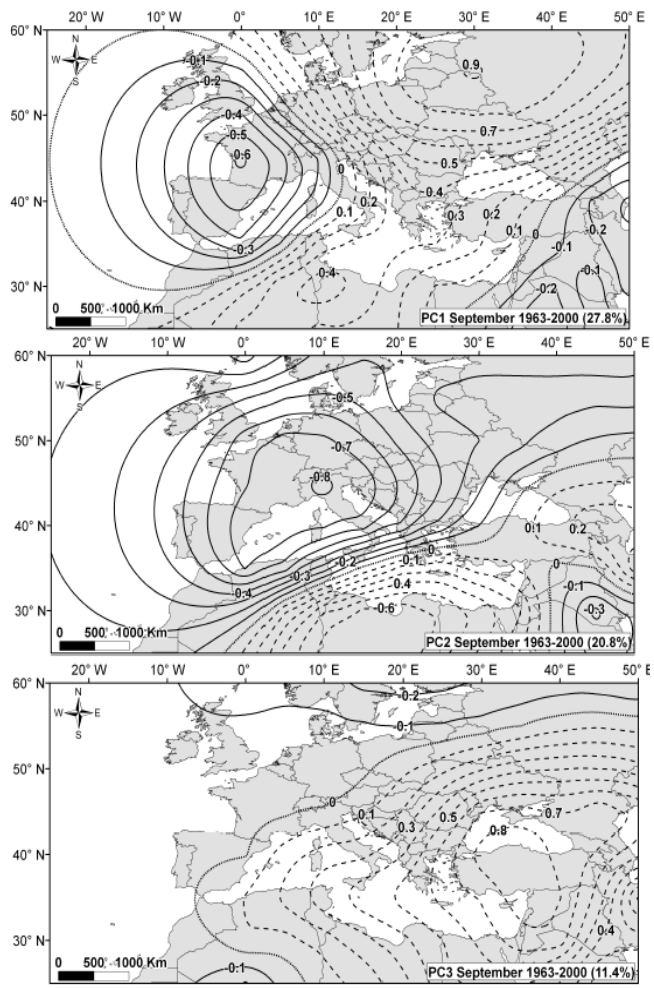

Figure 6. As in Figure 2, but for September 850 hPa level air temperatures: a) PC, b) PC2, c) PC3, respectively

About 60% of long-term variation in September 850 hPa temperatures is represented by the first three eigenvalues (Table 1). According to figure 7a, significant negative values observe over the Western Europe (France, Spain and Portugal around), whereas significant positive values indicate in Belarus and surrounding of Moscow. Negative loading indicate over the west of Europe. Negative values are interested in the Azores high pressure. Positive pattern displays over the Russia and surroundings. However, approaching from the northern European air masses and also the warming due to thermal effect brings mild weather over the western part of Europe in September (Figure 6a).

The second component accounts about 20.8% year to year variability of 850 hPa temperature in September (Table 1). The figure 7b indicates the prevailing pressure patterns in September. Negative pattern cover the whole of Europe originates in the Atlantic and northern European. Seasonal movements of ITCZ cause a positive pattern over the North Africa. Domain of ITCZ is shifted from northern latitudes to southern latitudes since September (Figure 6b).

A significant positive pattern is indicated over the Turkey by the PC3 loadings in the figure 7c. This pattern can be explained continuing influence of the monsoon low pressure over the Middle East and Turkey and presence of the dominant continental air masses over the Middle East and Levant (Figure 6c).

4. Conclusions

In this study is examined the regional character of 850 hPa temperature over Mediterranean Region changes long term summer series. In general, the summer climate of Mediterranean basin is formed with Atlantic and tropical origin circulation. Tropical circulation, shifted to more northern latitudes in summer season, has been a dominant circulation over the Mediterranean basin.

During the summer, especially in July and August, the Eastern Mediterranean (EM) is dominated by two persisting dynamic factors: subsidence (Alpert et al., 1990; Rodwell and Hoskins, 1996; Saaroni et al., 2003) and north-westerly cool Etesian winds (Saaroni and Ziv, 2000; Saaroni et al., 2003). Long-term average 850 hPa temperatures over the Western Europe and surroundings generally are controlled by the north and northeast Atlantic based systems beginning of summer. The Azores high pressure expanding to the north have controlled the warm and dry conditions over the Western Europe and Western and Central Mediterranean Basin over the level of 850 hPa during July and August.

According to Maheras and Kutiel (1999), high temperatures in the eastern Mediterranean in this season are associated with a weak depression centered over North Europe and west Europe, with a weak trough extending towards the Middle East (Persian Trough). Persian trough is also a non-migratory lower level trough extending from Asian monsoon over the Persian Gulf toward southern Turkey and Aegean Sea. This system persists during the summer months, mostly from June to September. This pressure pattern causes a weak westerly and northwesterly circulation mainly over the western Mediterranean bringing cooler air masses from the Atlantic into that region. This westerly flow is Etesian winds that are effective at lower levels in summer (Alpert et al., 1990; Saaroni and Ziv 2000; Ziv et al., 2004; Saaroni et al., 2010). In the previous studies were indicated by researchers that the linkage between Asian monsoon and the East Mediterranean summer climate, especially mid-level subsidence (Rodwell and Hoskins 1996; Ziv et al., 2004).

Warming surface temperatures have experienced over those regions because of subsidence. Its effect weakened after the 15th of August and has influenced over the Arabian Peninsula, Persia trough Turkey and surroundings.

Generally, the northwestern extension of monsoon circulation has controlled of 850 hPa temperatures over the Middle East, Iran, Turkey, the Balkans and the Caucasus in beginning June to September. Western Europe and the Western Mediterranean Basin temperatures influences from the Atlantic air masses in June. From the North Atlantic circulation has expanded into Central Europe and maritime air masses have influenced over the western to interior of Europe in July. The tropical circulation has effective from the Middle East to Russia. Eastern Europe, the Caucasus, the Balkans and Turkey (mostly Black Sea coastal zone) temperatures have been influenced by the monsoon circulation and thermal conditions in summer.

Finally, Turkey and surrounding have been experienced hot days and frontolysis due to effective atmospheric conditions in summer seasons. All urban regeneration projects and rural area planning should be considered the summer atmospheric conditions. These results should be regarded in light of projected future climate and potential impacts on health, agriculture, and water resources, against future water problems.

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