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Sea level pressure patterns associated with dry or wet monthly rainfall conditions in Turkey

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With 11 Figures

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Summary

Monthly rainfall totals at 7 stations across Turkey and sea level pressure (SLP) in 16 grid points in the region delimited by the 20° E and 50° E longitudes and by the 30° N and 45° N latitudes were analysed. Data were available for a period longer than sixty years. The standard deviations of SLP at each grid point for each month, were calculated and mapped. For each station, months were defined as *dry* or *wet* according to their z scores: ≤ -1.0 or ≥ 1.0 respectively. Maps showing the SLP z scores of the corresponding *dry* or *wet* months for each station were prepared. The maps, enable to distinguish between SLP patterns associated with dry or wet conditions. Furthermore, correlations between monthly rainfall in each of the stations and SLP at each grid point were performed. The correlation coefficients were mapped.

The main findings can be summarized as follows:

(a) The variability of the SLP decreases from the Balkans towards the Arabian Peninsula and is much larger in winter as compared with summer. (b) Relationship between rainfall in Turkey and the regional SLP is large in winter and non existing in summer. (c) Pressure patterns associated with *dry* conditions, show usually positive SLP departures, whereas, pressure patterns associated with *wet* conditions show usually negative SLP departures. (d) There is a great resemblance between pressure patterns associated with *wet* conditions and correlation maps of the same months.

1. Introduction

Very few studies regarding the spatial and temporal properties of annual and seasonal rainfall in Turkey were published until very recently. In the last few years several studies dealing with different aspects of the rainfall climatology and long-term rainfall variations in Turkey were published, e.g., Türkeş (1996, 1998, 1999), Kadioğlu and Şen (1998), Kadioğlu et al. (1999). This is probably due to major efforts done by the Turkish State Meteorological Service to provide long and reliable data series (Kadioğlu et al., 1999).

The above mentioned studies deal with different temporal or spatial aspects of the rainfall over Turkey. However, no study analysing the relationship with atmospheric pressure was published. Furthermore, there is no publication in which a differentiation between pressure patterns associated with either dry or wet conditions was presented. The present study aims to fill this gap.

Although Krichak et al. (2000), studied synoptic patterns associated with dry or wet conditions in the eastern Mediterranean, there are several important differences between both studies. Krichak et al., used rainfall data from Israel to define the dry or wet months for the entire eastern Mediterranean, while we defined them independently for each region in Turkey based on Turkish data. As a consequence of it, they presented average situations for the entire region, while in the present study, we focus separately on each region in Turkey.

Turkey was divided into seven homogenic regions based on similarities of the rainfall regime within each region. The delimitation of these regions and the description of their rainfall characteristics, were widely discussed and presented by Türkeş (1996, 1998). An adequate information on Turkey's general geography including the main climatic types has also been presented in a recent study by Türkeş (2000). Namely, the rainfall regions of Turkey are:

1–Marmara Transition (MRT): Quite uniform rainy with a warm and light rainy summer.
2–Black Sea (BLS): Uniform rainy with a maximum in autumn; temperate.
3–Mediterranean (MED): Markedly seasonal with a cool and heavy rainy winter and a hot dry summer; humid and semi-humid subtropical.
4–Mediterranean to Central Anatolia Transition (MEDT): Moderate rainy winter and spring.
5–Continental Central Anatolia (CCAN): Cool rainy spring and cold rainy winter, and warm and light rainy summer; semi-arid and dry semi-humid steppe.
6–Continental Eastern Anatolia (CEAN): Cool rainy spring and early summer with a very cold and snowy winter; dry semi-humid and semi-humid steppe and highland.
7–Continental Mediterranean (CMED): Seasonal with a rainy winter and spring and a severe hot dry summer; semi-arid and dry semi-humid subtropical.

The relationship between precipitation totals and pressure patterns in countries near and around Turkey were recently published. Kutiel (1991 and 1994) related variations in the spatial and temporal properties of the rainfall regime in the Galilee (Northern Israel) to parallel changes in sea level pressure (SLP hereafter) in the Mediterranean. Kutiel et al. (1996a and 1996b) analysed the relationship between circulation indices and dry or wet periods at several locations in the Middle East excluding Turkey. In a recent article (Kutiel et al., 1998) the authors analysed singularities in the rainfall regime in Greece and in Israel and their relevance to dry and wet spells in both countries. Kutiel and Paz (1998) studied the relationship between SLP and monthly rainfall totals in Israel.

The scope of the present study is to show relationship between rainfall variations in each of the seven rainfall regions of Turkey as delimited by Türkeş (1996) and the regional SLP variations, and to determine SLP patterns associated with *dry* or *wet* rainfall conditions in each of these regions.

2. Data and methodology

Rainfall data comprised monthly totals for a period longer than sixty years in seven stations across Turkey, (Table 1). Each of the selected stations represents a different region as defined by Türkeş (1996). SLP data were available for 16 grid points within the region delimited by the 20° E and 50° E meridians and by the 30° N and 45° N parallels, covering the entire territory of Turkey and its immediate vicinity (Fig. 1). SLP data were obtained from the *World Climate Disk* CD-ROM (1992).

Dry and *wet* conditions in each month were defined independently for each station, using standardized z scores in a similar way done by Kutiel et al. (1996a) or Kutiel and Paz (1998).

For each month the data were standardized as follows:

$z = (x_i - \bar{x})/\sigma$

where: x_i *is the monthly rainfall in the year* i; $\bar{x}$ is the long-term monthly rainfall average and σ is its standard deviation.

Table 1. Information on Turkey's stations chosen for the analysis

Rainfall Region	Station	Station ID number	Observation period	Longitude	Latitude
MRT	Göztepe (Istanbul)	17062	1929–1996	29° 05′	40° 58′
BLS	Giresun	17034	1929–1996	38° 23′	40° 55′
MED	Muğla	17292	1926–1996	28° 22′	37° 13′
MEDT	Uşak	17188	1929–1996	29° 24′	38° 41′
CCAN	Ankara	17130	1926–1996	32° 53′	39° 57′
CEAN	Sarikamiş	17692	1930–1996	42° 34′	40° 20′
CMED	Diyarbakir	17280	1929–1996	40° 12′	37° 53′

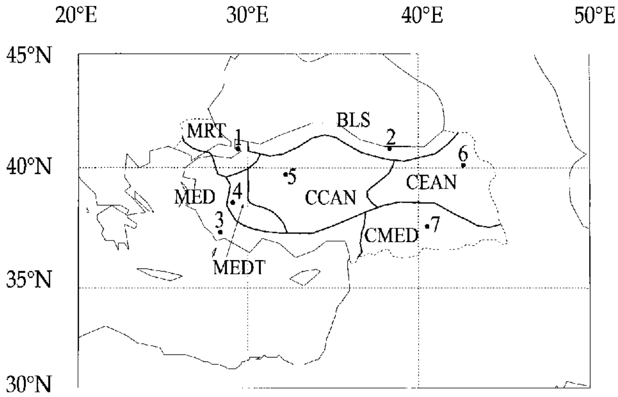

Fig. 1. Location map showing the different rainfall stations used in the present analysis: 1–Göztepe, 2–Giresun, 3–Muğla, 4–Uşak, 5–Ankara, 6–Sarikamiş, 7–Diyarbakir. The delimitation of the different rainfall regions in Turkey were plotted after Türkeş (1996). SLP data were available in grid points within the region delimited by the 20° E and 50° E meridians and by the 30° N and 45° N parallels

A month for which the total rainfall was equal or less than $\bar{x} - \sigma$ was defined as *dry*. Similarly, a month for which the total rainfall was equal or greater than $\bar{x} + \sigma$ was defined as *wet*. The mean standardized SLP departure of all *dry* months at each grid point was calculated and mapped. The same was done for the *wet* months, yielding 24 monthly maps (12 for *dry* conditions and 12 for *wet* conditions) for each station.

Furthermore, for each month and each station, correlation coefficients (Pearson's *r*) were calculated between the total monthly rainfall and the mean monthly SLP at each of the sixteen grid points. A total of 1344 correlation coefficients (7 (stations) $*$ 16 (grid points) $*$ 12 (months)) were calculated. The correlation coefficients (c.c. hereafter) between the rainfall at each station and SLP at grid points enabled to prepare correlation maps (see, e.g., Stidd, 1954; Klein and Bloom, 1986). Correlation coefficients larger than $|0.25|$ were statistically significant at the 0.05 significance level of the Student's *t* distribution.

We preferred to use the *Pearson's r parametric test* instead of a non-parametric correlation technique (e.g., Spearman's rank correlation coefficient r_s). This can be justified as stated by Barber (1988): "*When a data set satisfies all the assumptions of a given parametric test, the parametric test should be applied. Any non-parametric alternative is almost always significantly less powerful than the comparable parametric procedure. The probability of making a Type I error is usually appreciably lower with parametric tests. However, violations of a parametric test's assumptions can change the sampling distribution of the test statistic and thus the power of the test.*" "*The size of the available sample is an important consideration in determining whether to use a parametric or non-parametric test. In general, the larger the sample, the more advantageous a parametric test becomes. The implications of the central limit theorem support this assertion. Where sample size is large, the presence of non-normality is often insignificant.*" In addition of these theoretical assessments, it is well-known that rank correlation coefficients can not distinguish linear from nonlinear monotonic functions, whereas Pearson's *r* is a measure of the linear association between two variables.

Drawing of correlation maps is a widely used methodology to relate pressure patterns with precipitation totals (e.g., Stidd, 1954; Kutiel, 1994). The correlation maps depict the favourable pressure conditions for a *wet* month. Positive c.c., should be interpreted as a centre of high pressure and thus, the derived circulation is clockwise. While, negative c.c., represent a centre of low pressure and the circulation is accordingly counterclockwise. As there is not a simple way to calculate c.c. of *dry* conditions, no such maps were prepared. However, the pressure conditions related to *dry* conditions should be regarded to be inverse to those depicted in the maps for *wet* conditions.

All maps were drawn using MacGridzo software, based on moving weighted least squares (MWLS) algorithm (MacGridzo, 1991, pp. 120–121).

3. Results

The spatial distribution of the standard deviations (SD) of SLP at the various grid points for the different months is illustrated in Fig. 2 and the annual course at each grid point is illustrated in Fig. 3.

Figure 4 shows the monthly distribution of the percentage of significant c.c. out of all c.c. Fig. 5 illustrates the pressure departures for *dry* or *wet* conditions and the spatial patterns of the c.c. of the rainfall at Göztepe with SLP for the various months. Figures 6, 7, 8, 9, 10 and 11 also illustrate

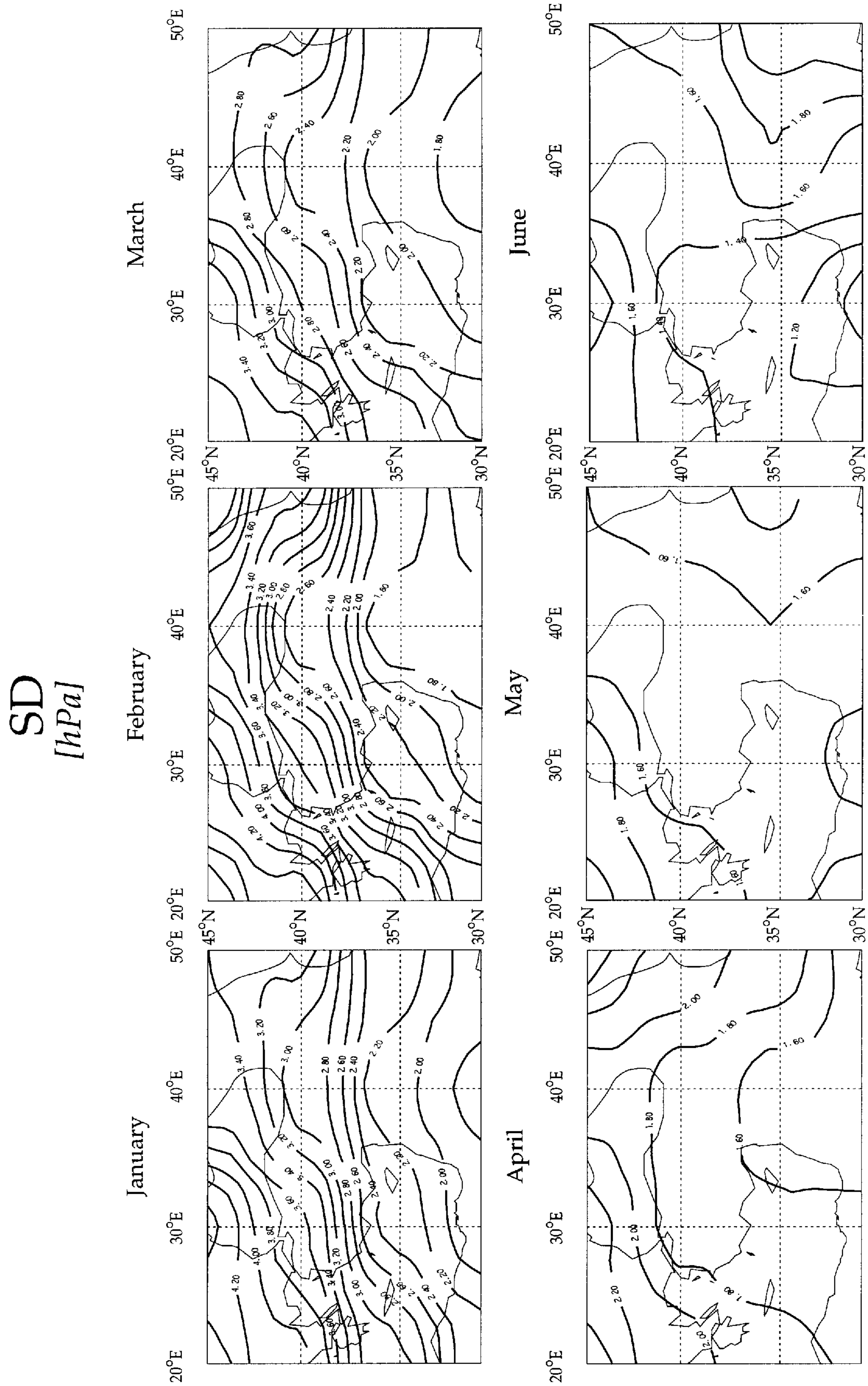

Fig. 2. The spatial distribution of the standard deviation of SLP for the different months

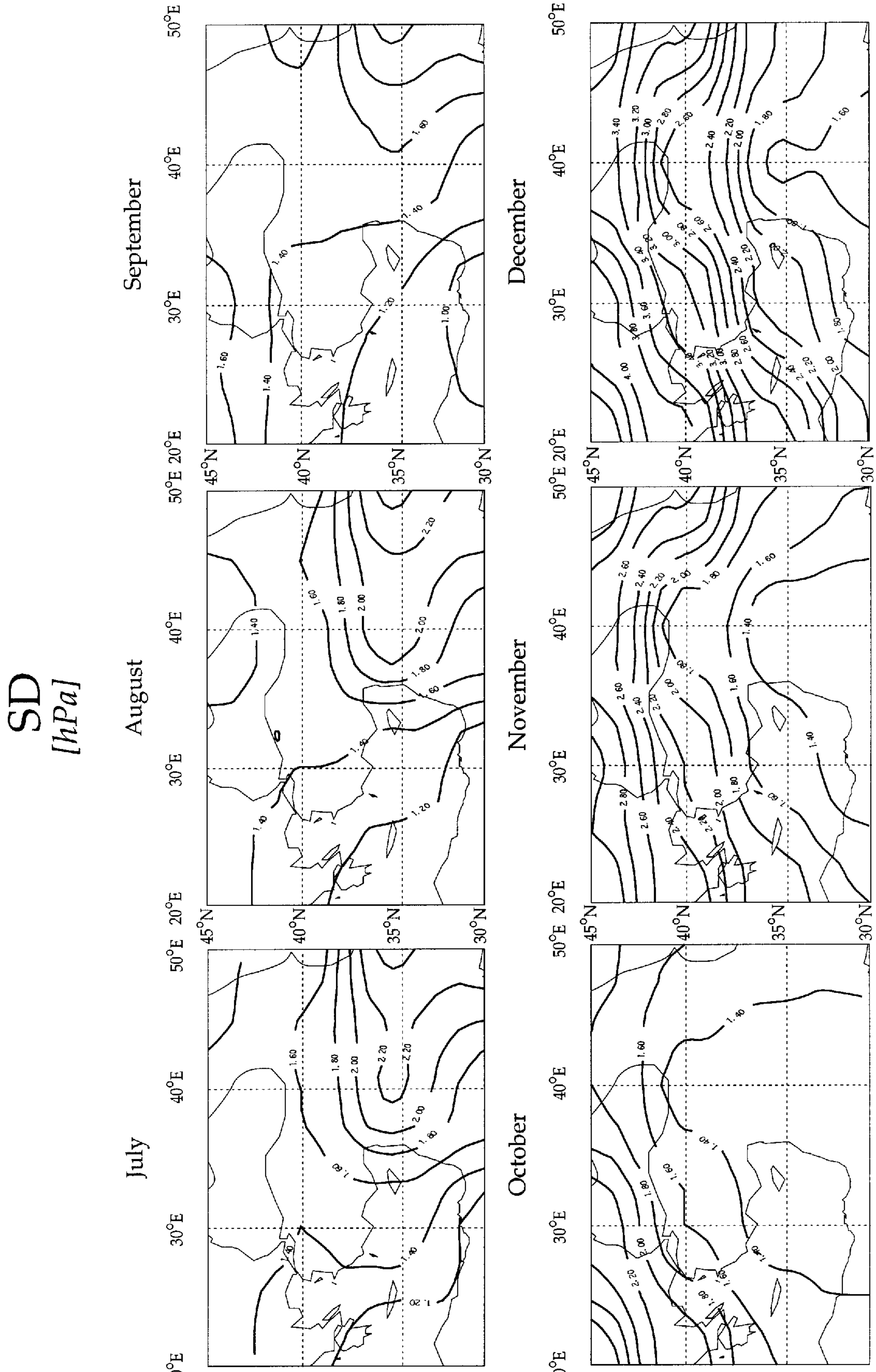

Fig. 2 (*continued*)

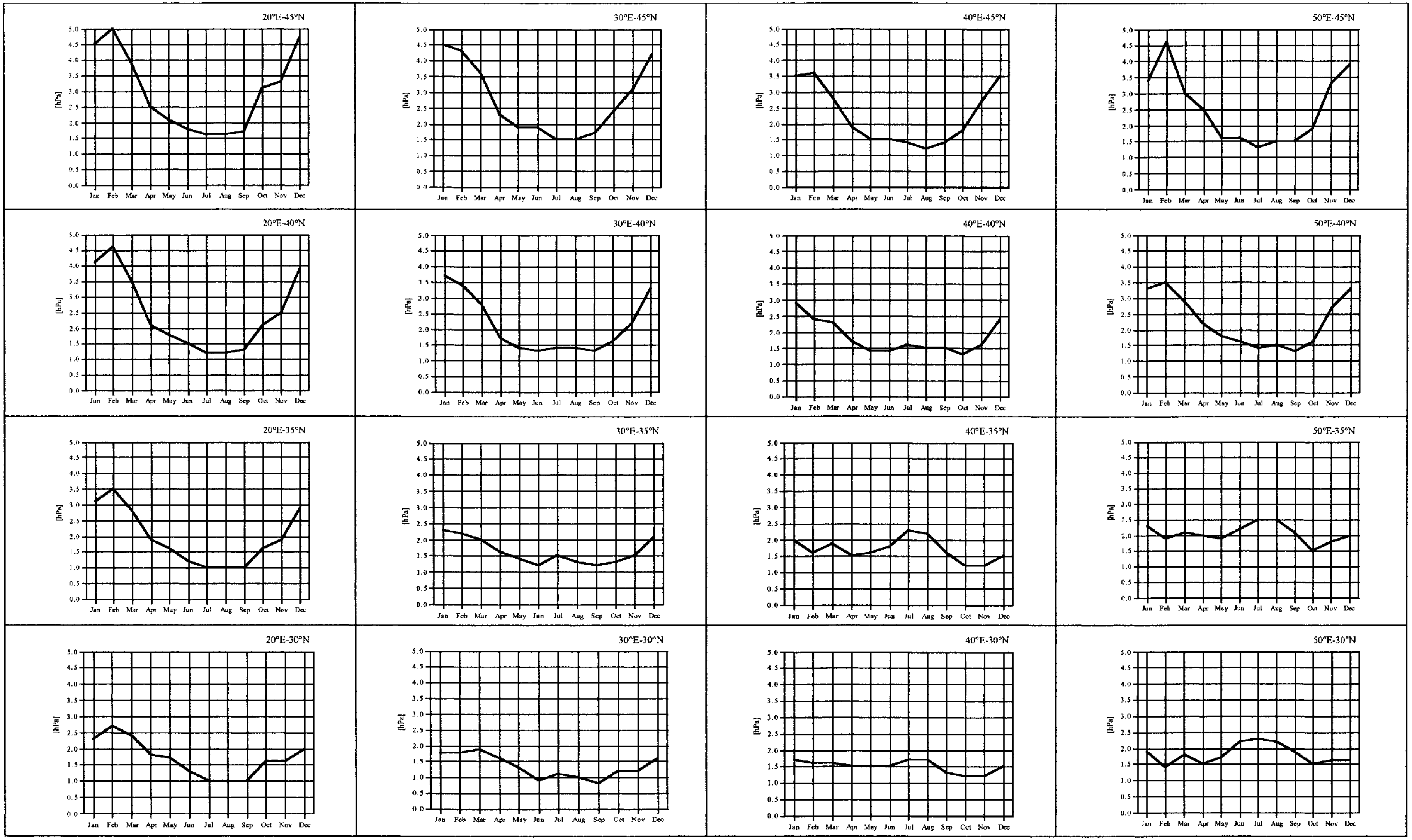

Fig. 3. The annual course of the standard deviation of SLP at the various grid points

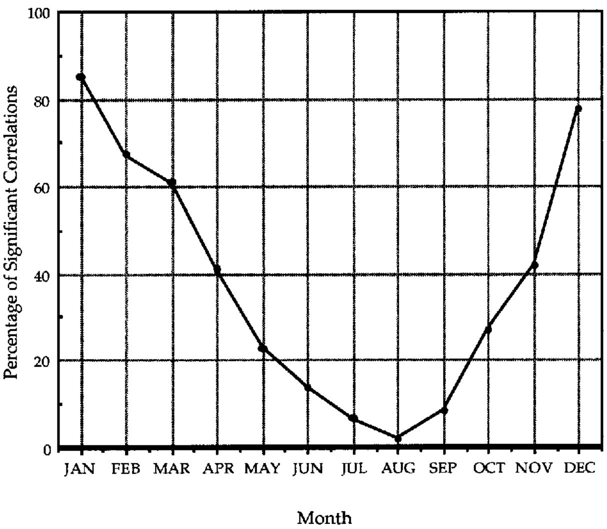

Fig. 4. The annual course of the significant correlations between rainfall and SLP at grid points

the same but for the stations of Giresun, Muğla, Uşak, Ankara, Sarikamiş and Diyarbakir, respectively.

Kutiel and Paz, 1998, have shown and explained why, the spatial patterns of SLP of the *wet* conditions were very similar to the spatial patterns of the correlation maps for Israel. In the present study, we may observe also a similarity between these two sets of maps. This fact increases our confidence in the results and their interpretation. Although different data sets (only *wet* months versus all months) and different variables (standardized pressure departures in hPa versus c.c.) are drawn, the derived circulation, in both cases pertaining to *wet* conditions, is very similar regardless the methodology used.

3.1 Variability of the sea level pressure

Spatial and temporal properties of SLP over the entire Mediterranean and major parts of Europe were widely discussed by Kutiel (1991). In the present study a different aspect not addressed in this mentioned article was studied: the spatial and temporal distribution of the SD of SLP over the study area. The SD of SLP indicates to what extent the monthly averages are meaningful and expectable in case of small SDs, or meaningless and unexpectable in case of large SDs.

Figure 2, illustrates the fact that monthly SD is in general larger over the Balkans region (northwestern part) and smaller over parts of Iraq, Iran and the Arabian peninsula (southeastern part). In other words, one should expect smaller year to year variations of monthly SLP over the southeastern region as compared with the northwestern region. However, in Fig. 3, one can see that the above scheme is too simplistic and that there is a clear annual course of the SDs of SLP. Generally, SDs are much larger in winter months and decrease considerably in summer months, meaning that summers are very alike each other while there are considerable differences from one winter to the other, at least from the SLP point of view. However, in the southeastern corner of the study region (namely grid points 40° E–35° N, 50° E–35° N and 50° E–30° N and to some extent also 40° E–30° N), the annual course of the SD shows a different behavior, with the maximum occurring in summer. The implications of these results on the relationship with *wet* or *dry* conditions over Turkey will be discussed later.

3.2 Temporal analyses of correlation fields and pressure patterns associated with dry or wet conditions in the various regions

Figure 4 illustrates the annual distribution of significant correlations between rainfall and SLP at grid points. It can easily be observed that the relationship between rainfall and pressure is stronger in winter and weaker in summer. In winter, (December and January) 80% or more of the c.c. are statistically significant, in February and March about 60% of the c.c., in November and in April about 40% of the c.c. In summer, (July–September), this figure drops to 10% or less. Türkeş (1998), found similar results but for relationships between the lower troposphere heights and rainfall, by correlating the normalized rainfall anomalies of Turkey's 91 stations with the normalized 700 hPa geopotential heights at Göztepe (Istanbul). The c.c. between winter rainfall and geopotential heights were negative and significant at the 0.01 level throughout Turkey, except the Black Sea region, whereas summer rainfall had a distribution pattern of weaker but positive c.c. over most of Turkey.

These results should be interpreted as a greater dependence of the rainfall on regional circulation in winter, while in summer, the rainfall is localized and caused by systems smaller than synoptic or regional scale, mainly by local convective

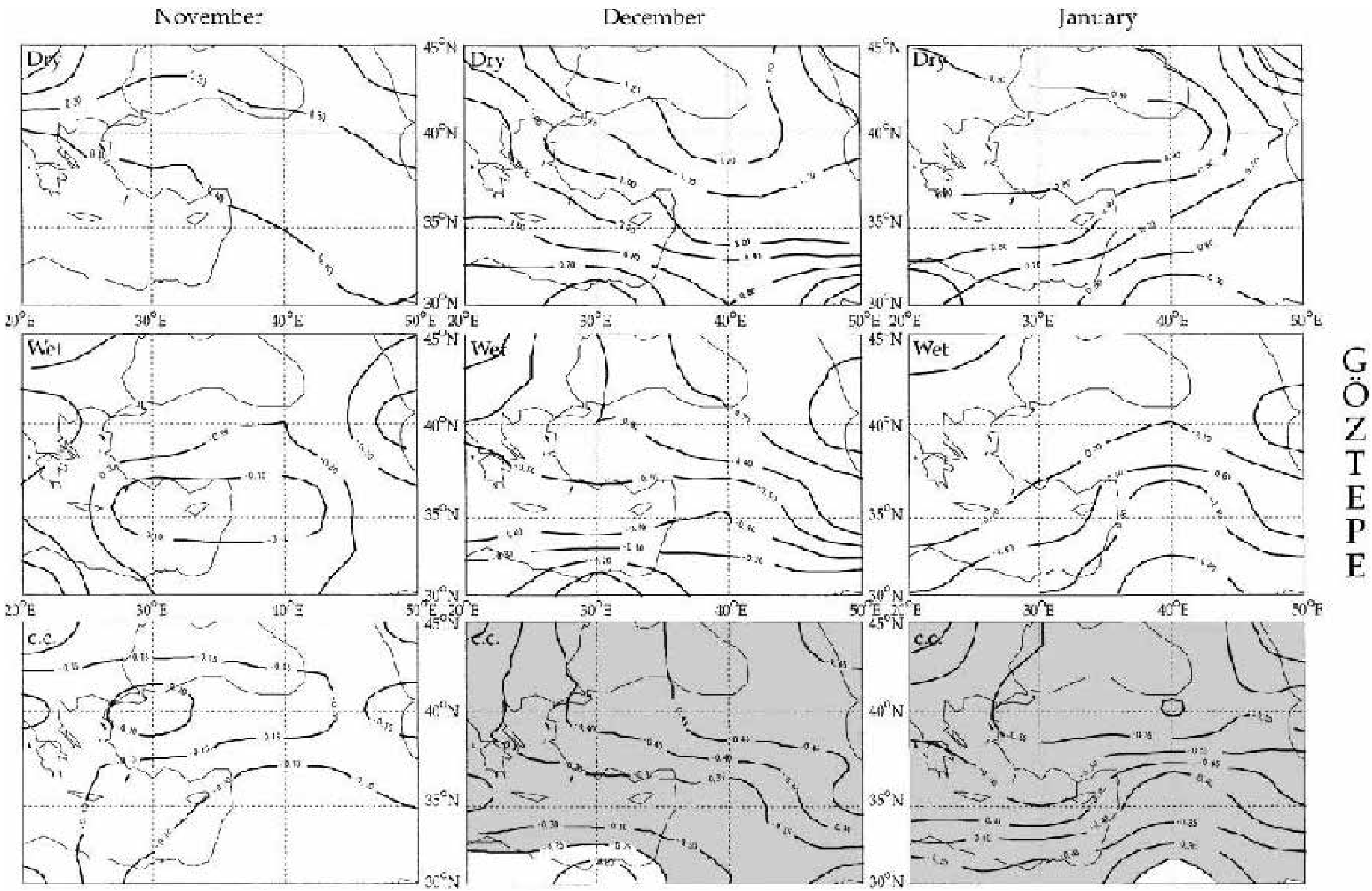

Fig. 5a. The spatial patterns of the standardized departures of the SLP for *dry* (top), or *wet* (centre) conditions, and the c.c. of the rainfall with the SLP (bottom) for Göztepe in November, December and January. The shaded regions in bottom maps represent c.c. significant at the 0.05 significance level. The station is marked with a dot

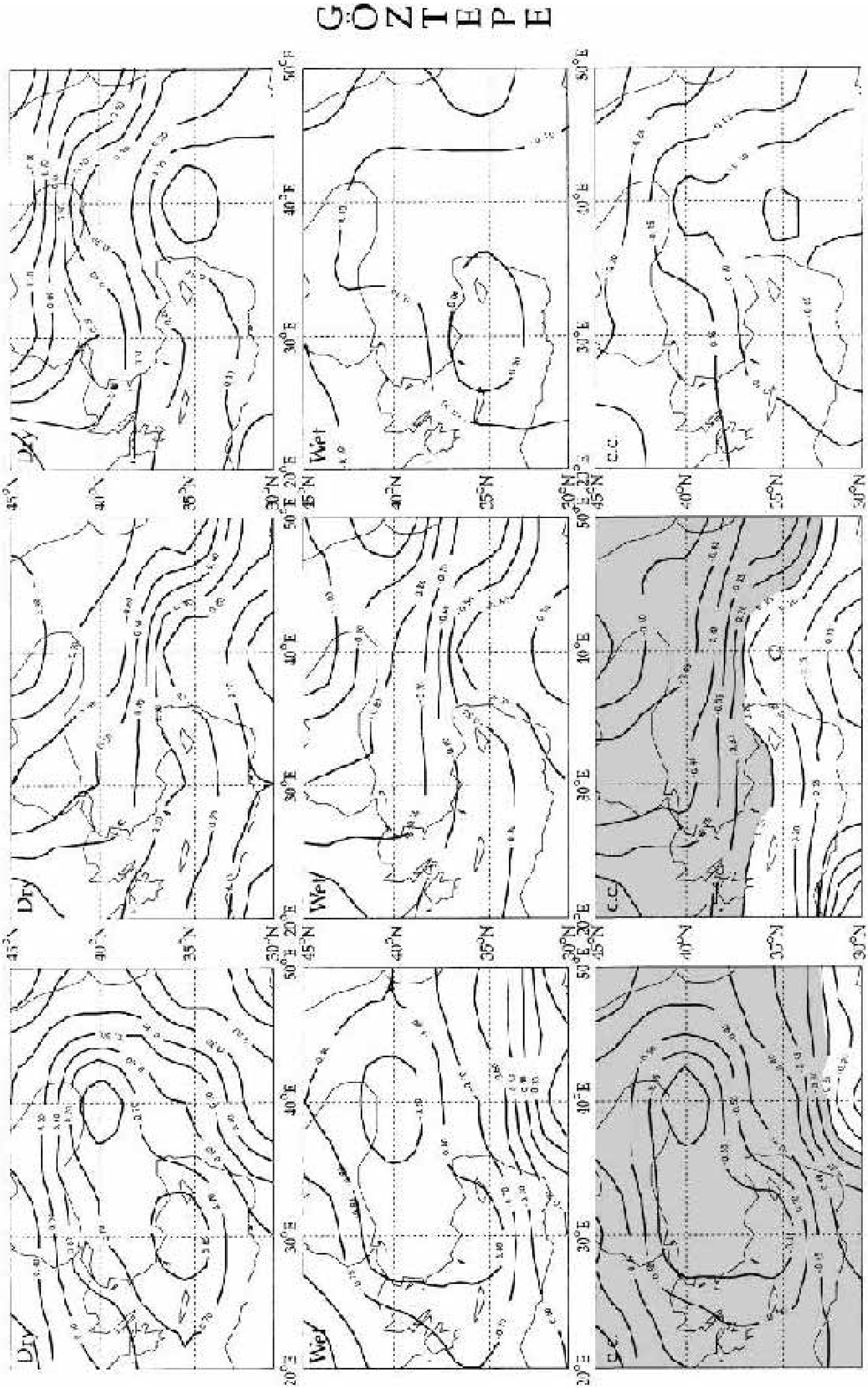

Fig. 5b. Same as Fig. 5a, but for February, March and April

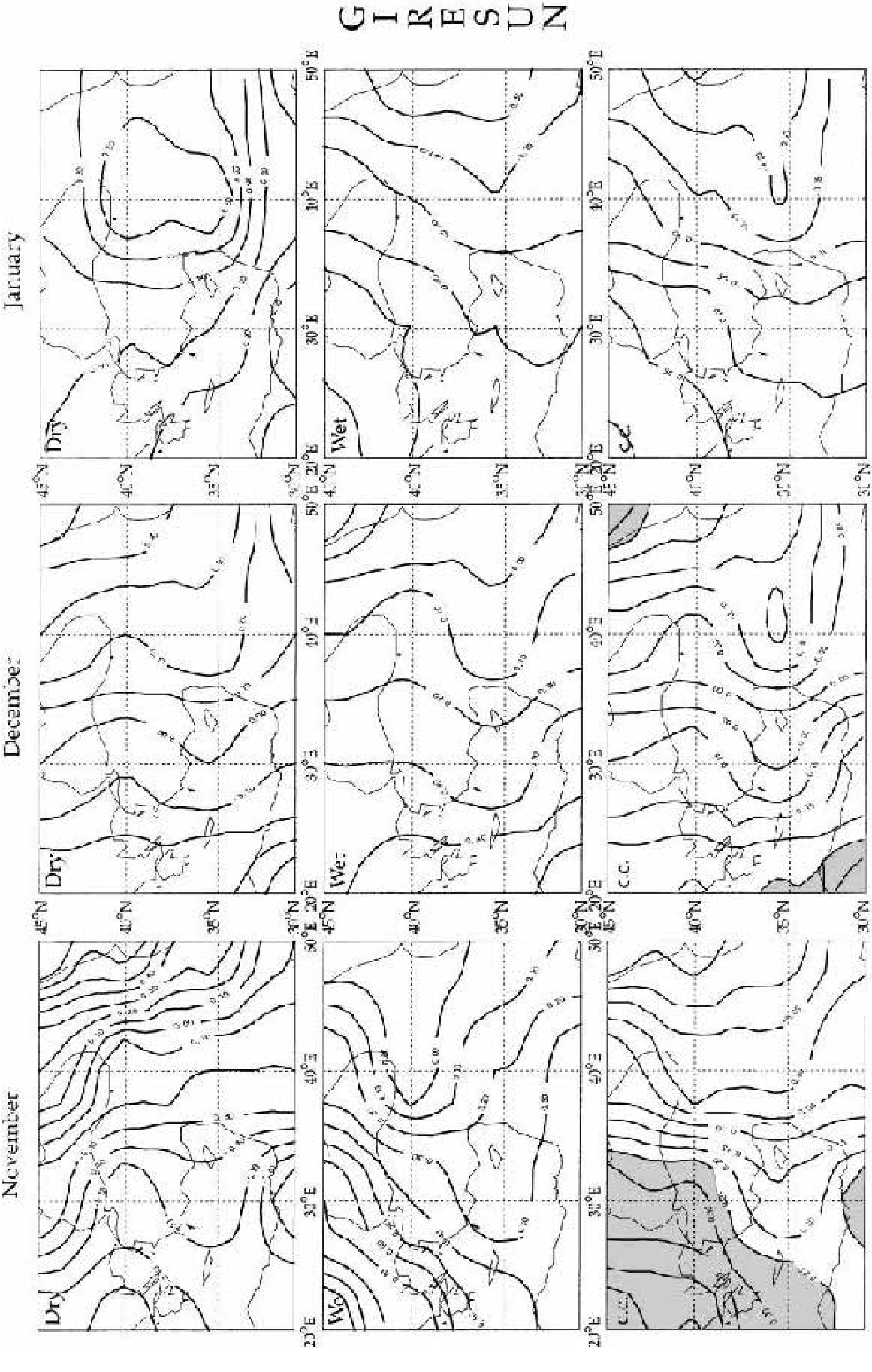

Fig. 6a. Same as Fig. 5a, but for Giresun

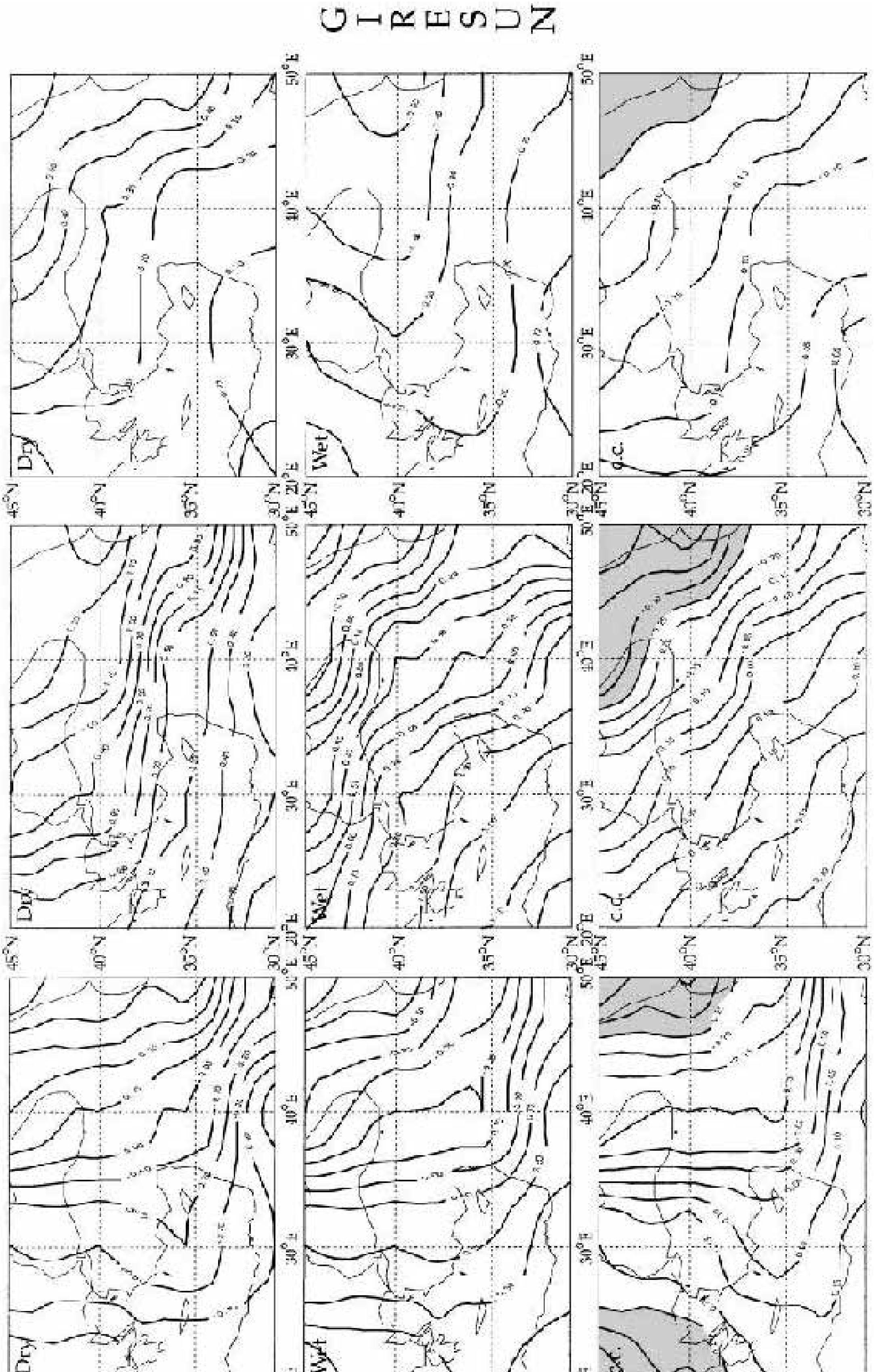

Fig. 6b. Same as Fig. 5b, but for Giresun

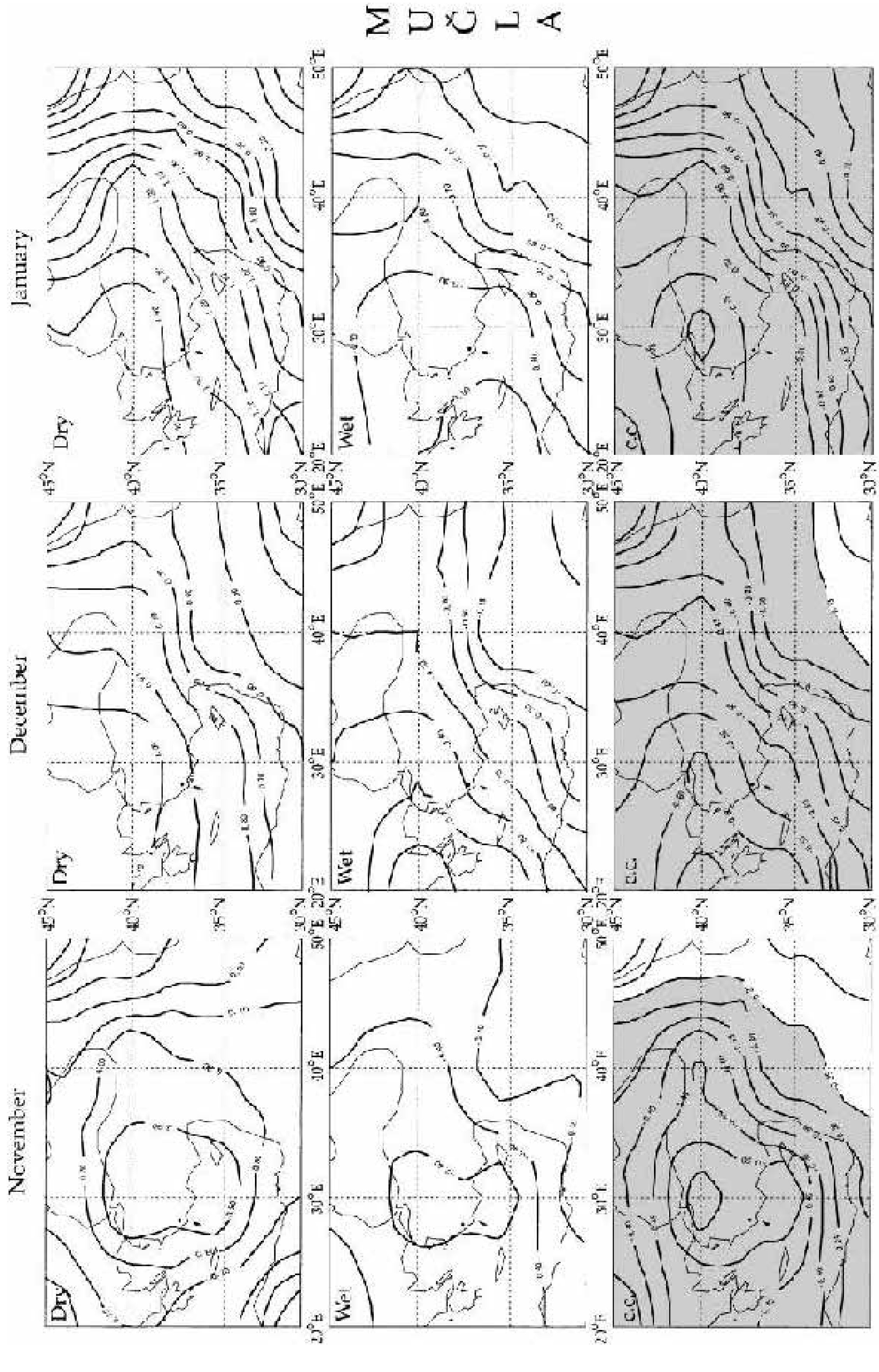

Fig. 7a. Same as Fig. 5a, but for Muğla

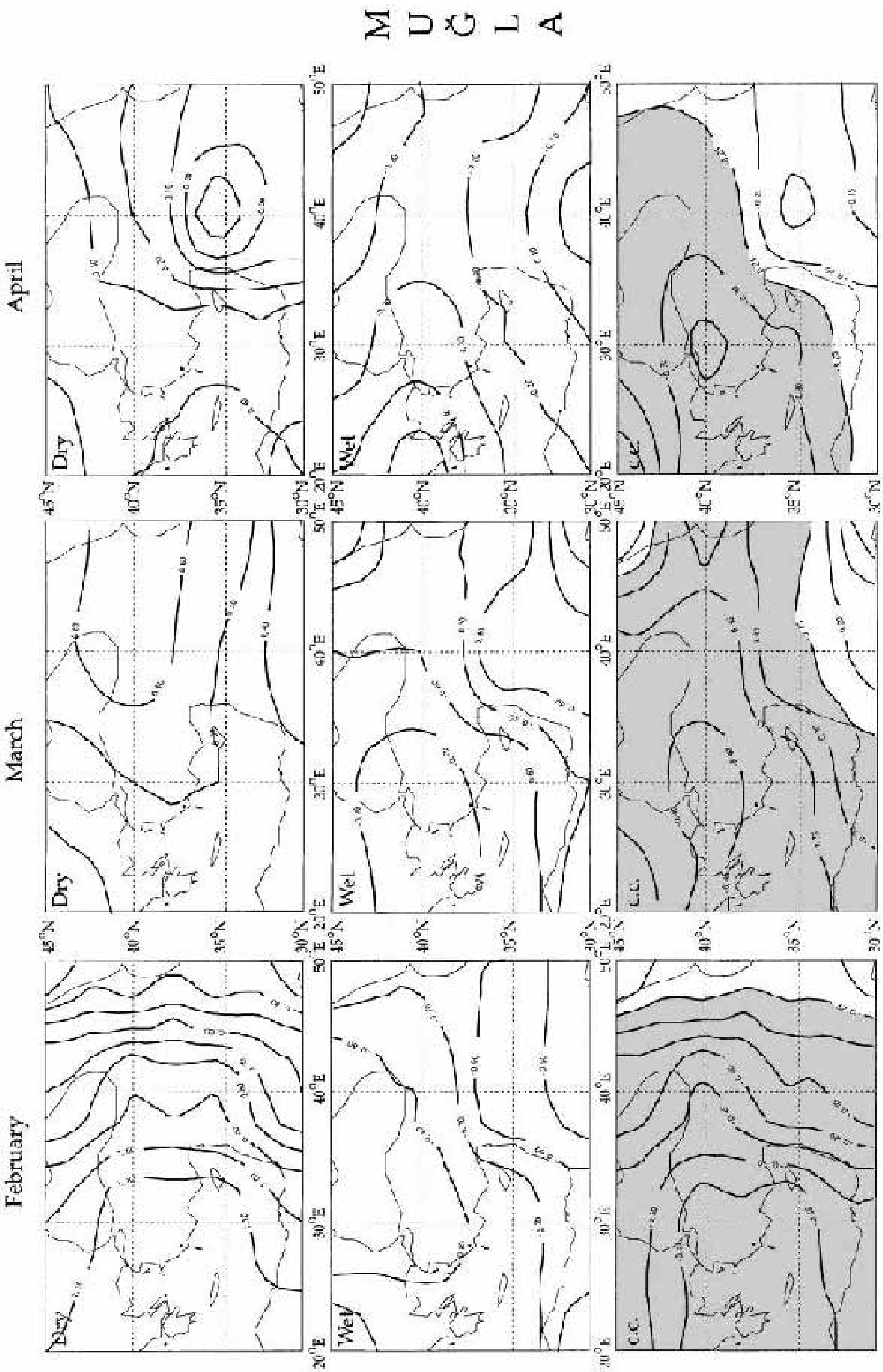

Fig. 7b. Same as Fig. 5b, but for Muğla

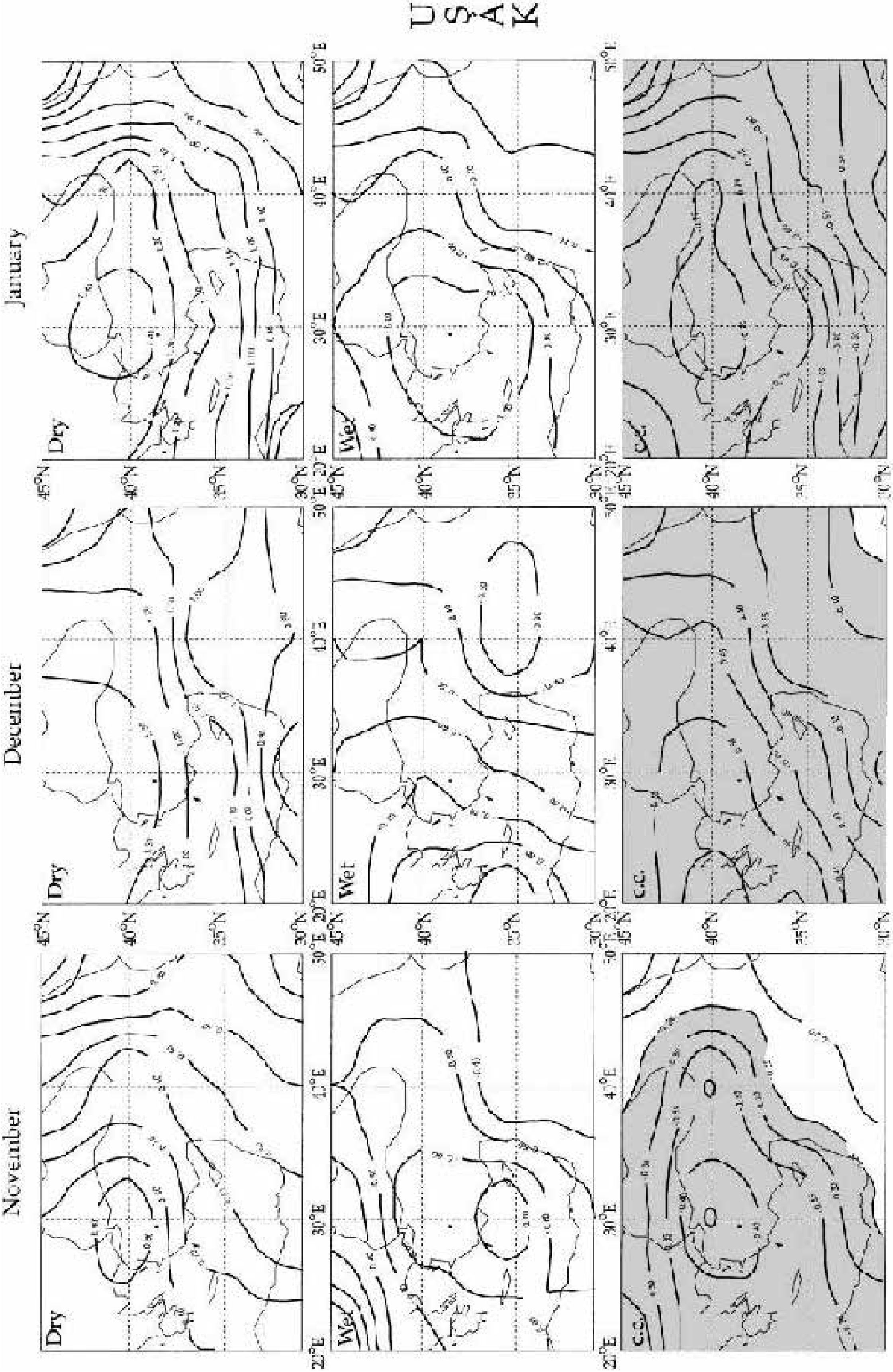

Fig. 8a. Same as Fig. 5a, but for Uşak

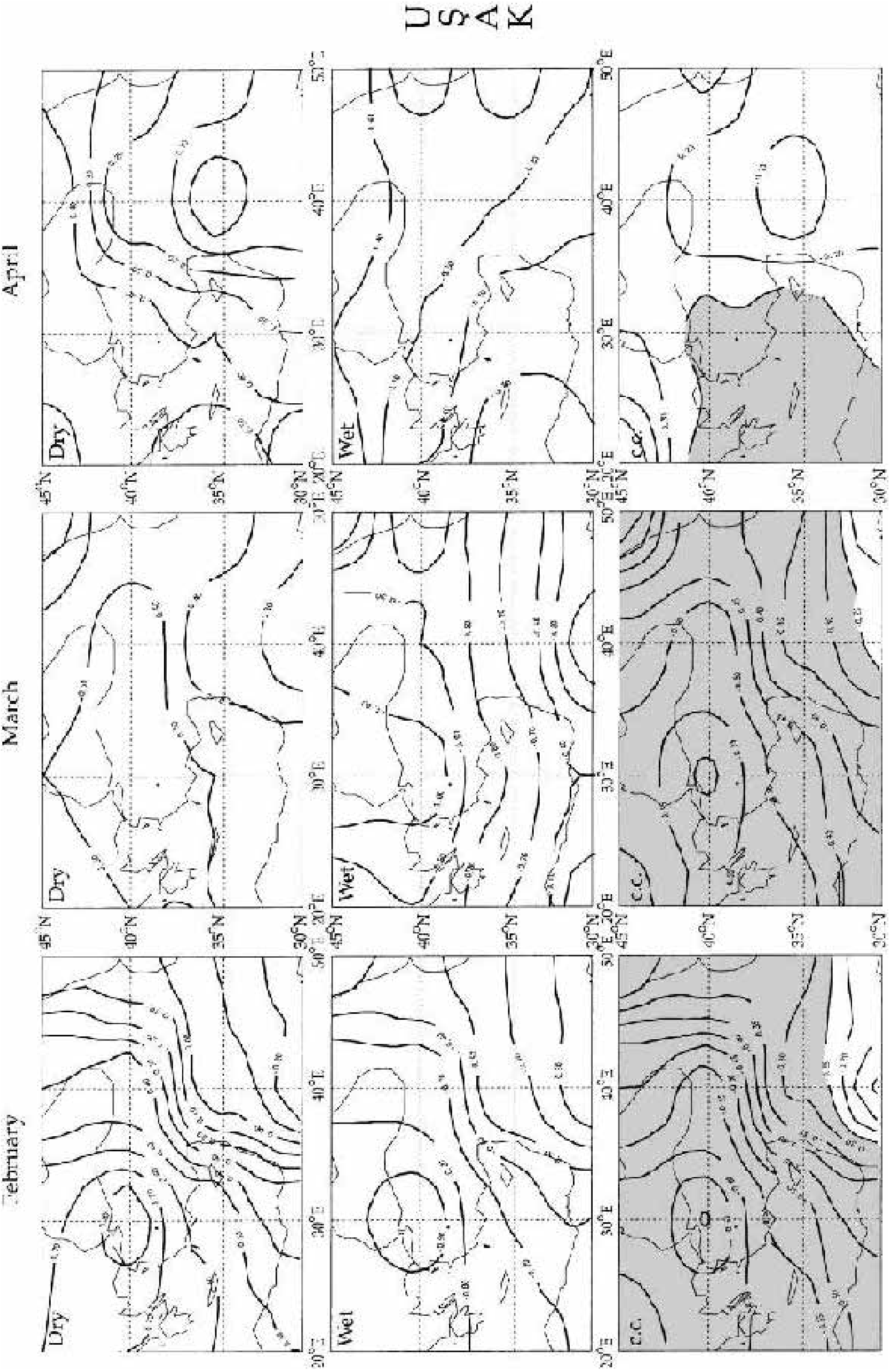

Fig. 8b. Same as Fig. 5b, but for Uşak

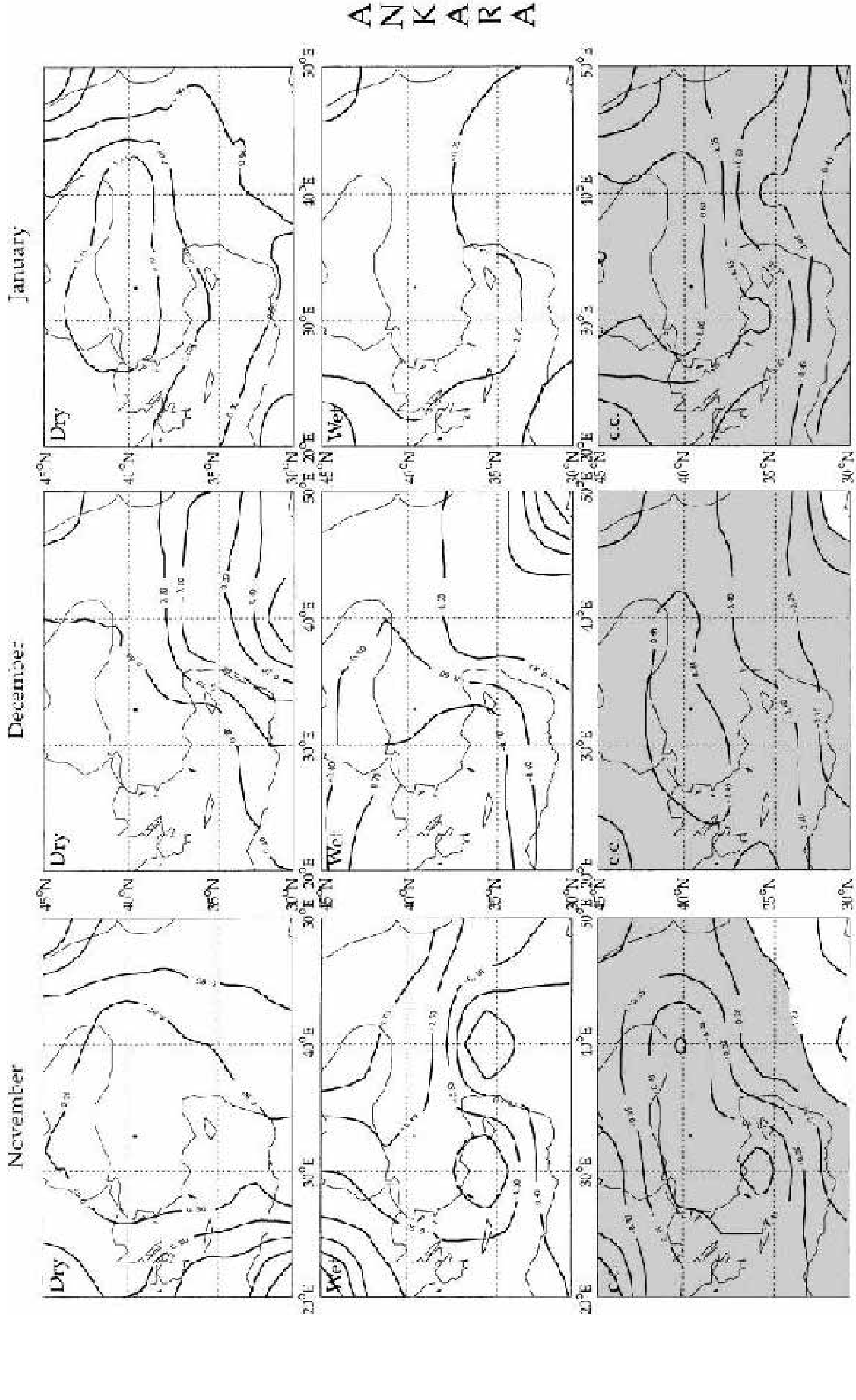

Fig. 9a. Same as Fig. 5a, but for Ankara

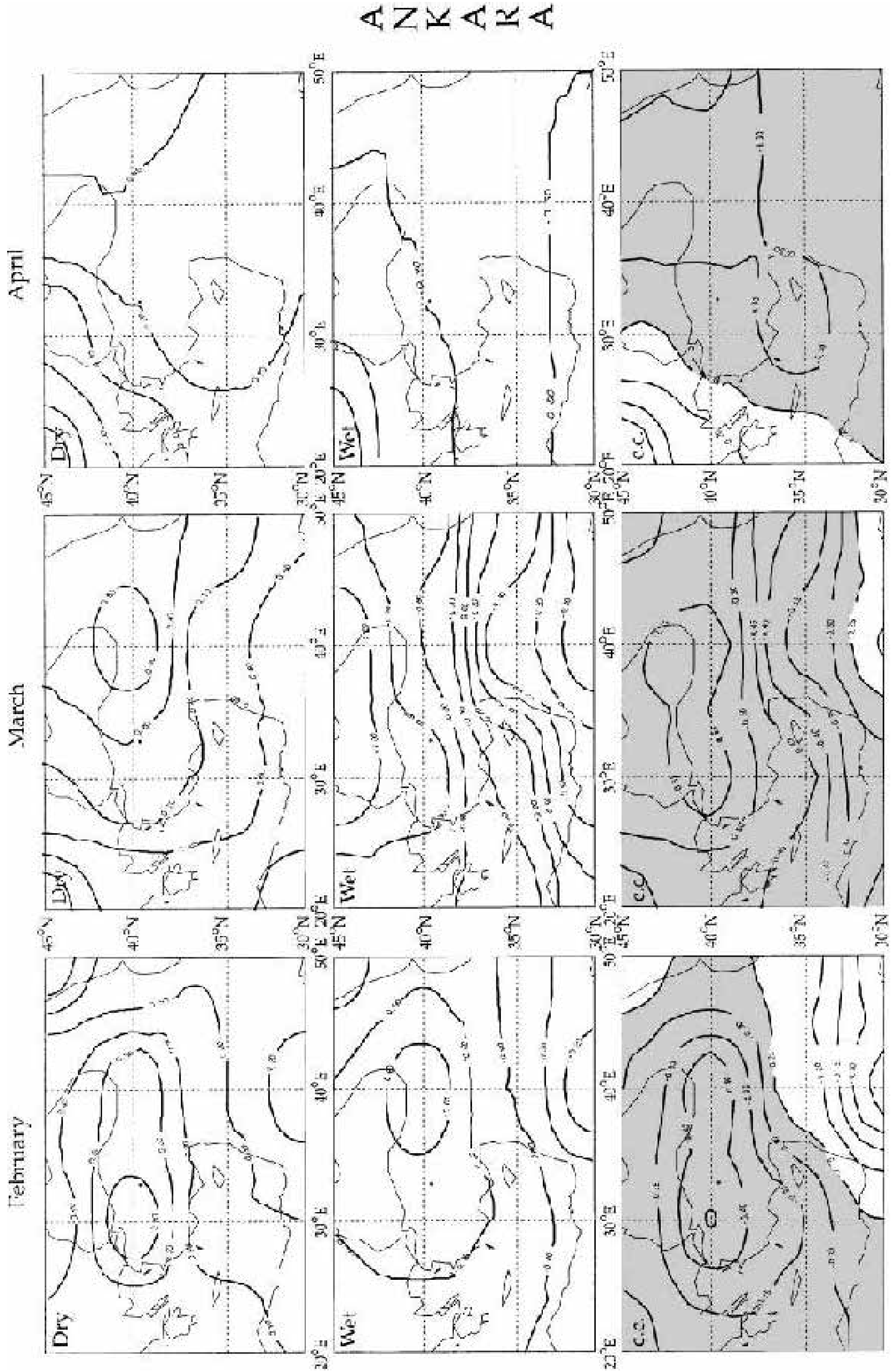

Fig. 9b. Same as Fig. 5b, but for Ankara

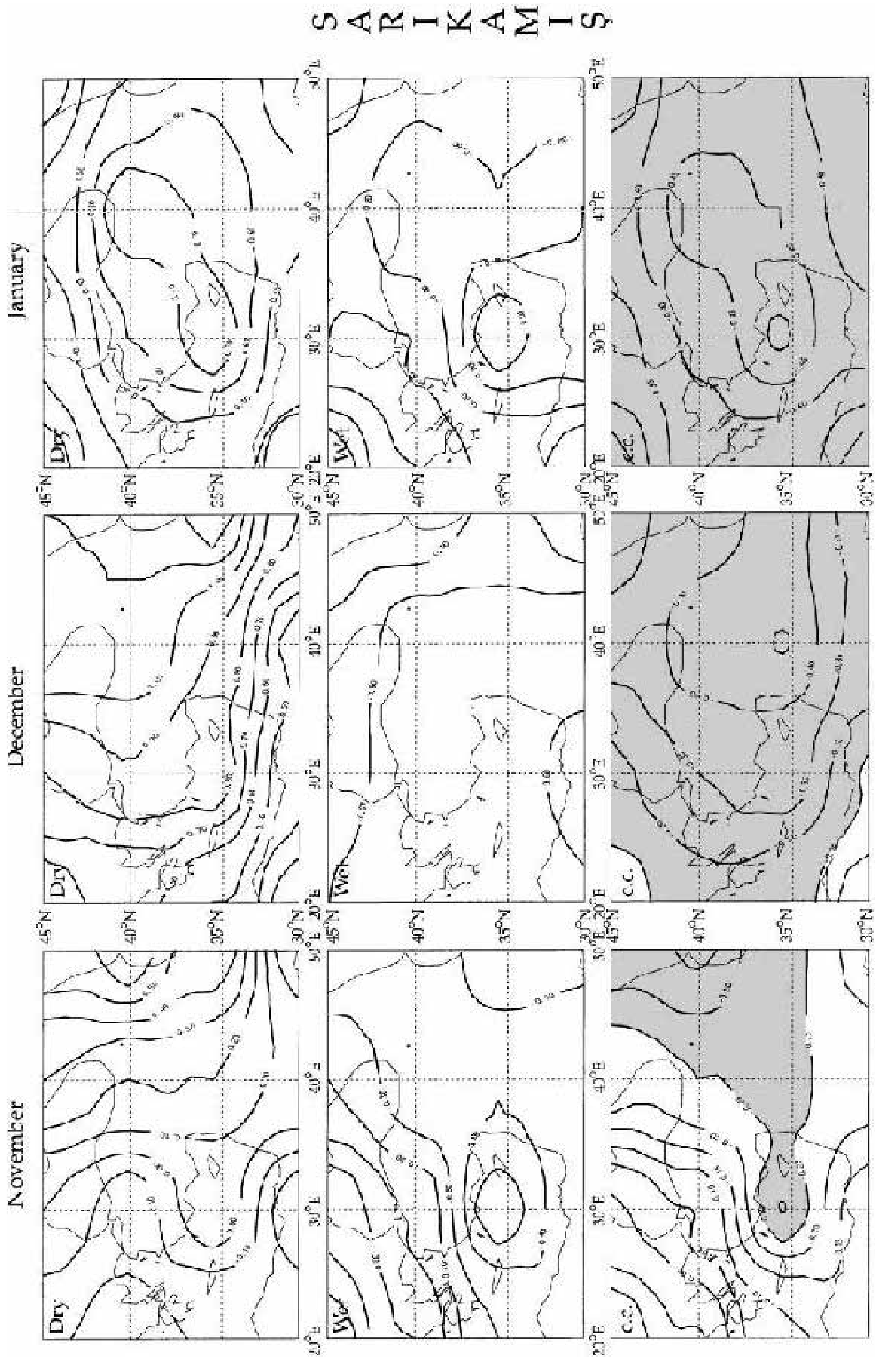

Fig. 10a. Same as Fig. 5a, but for Sarikamiş

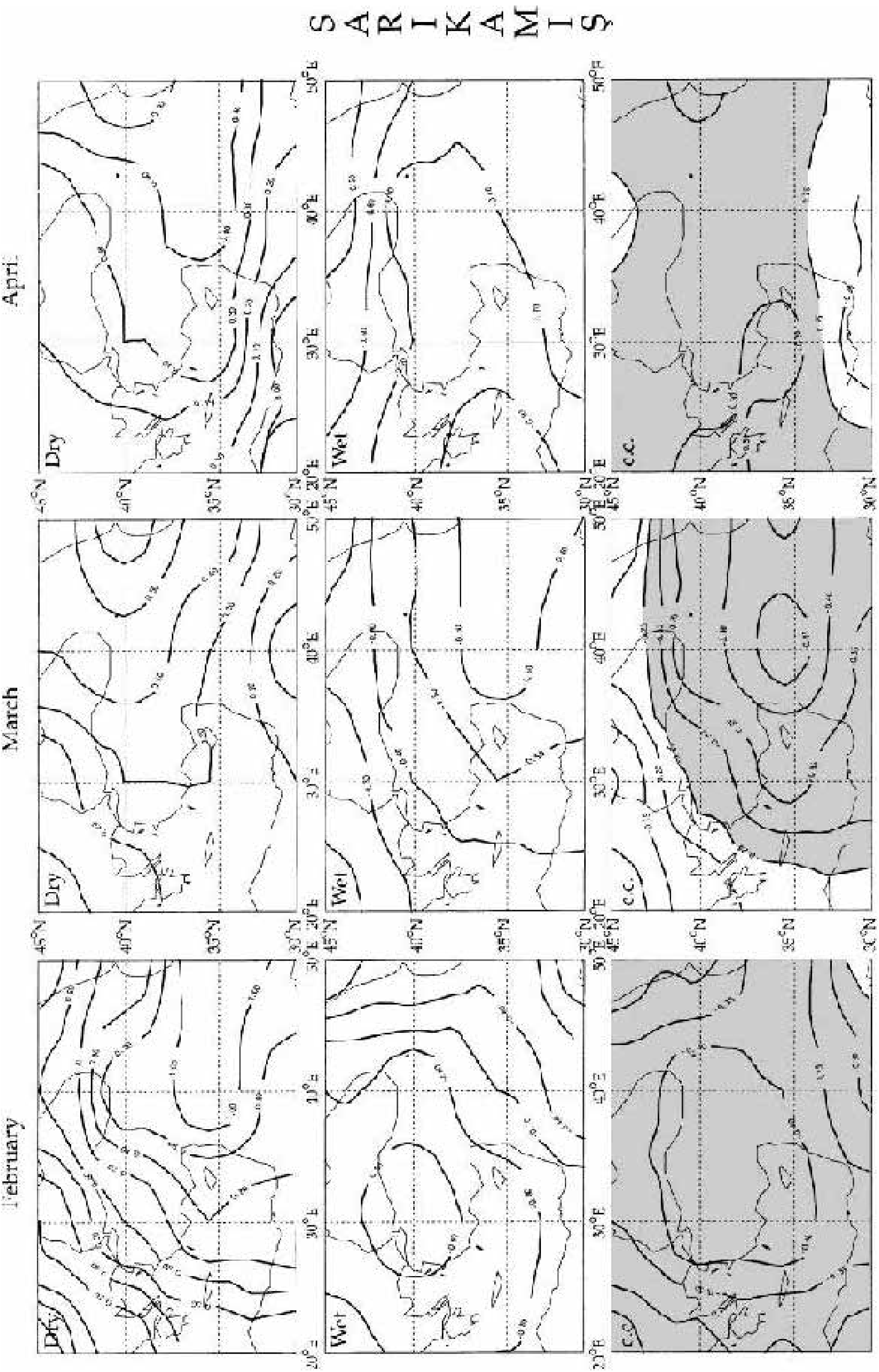

Fig. 10b. Same as Fig. 5b, but for Sarikamiş

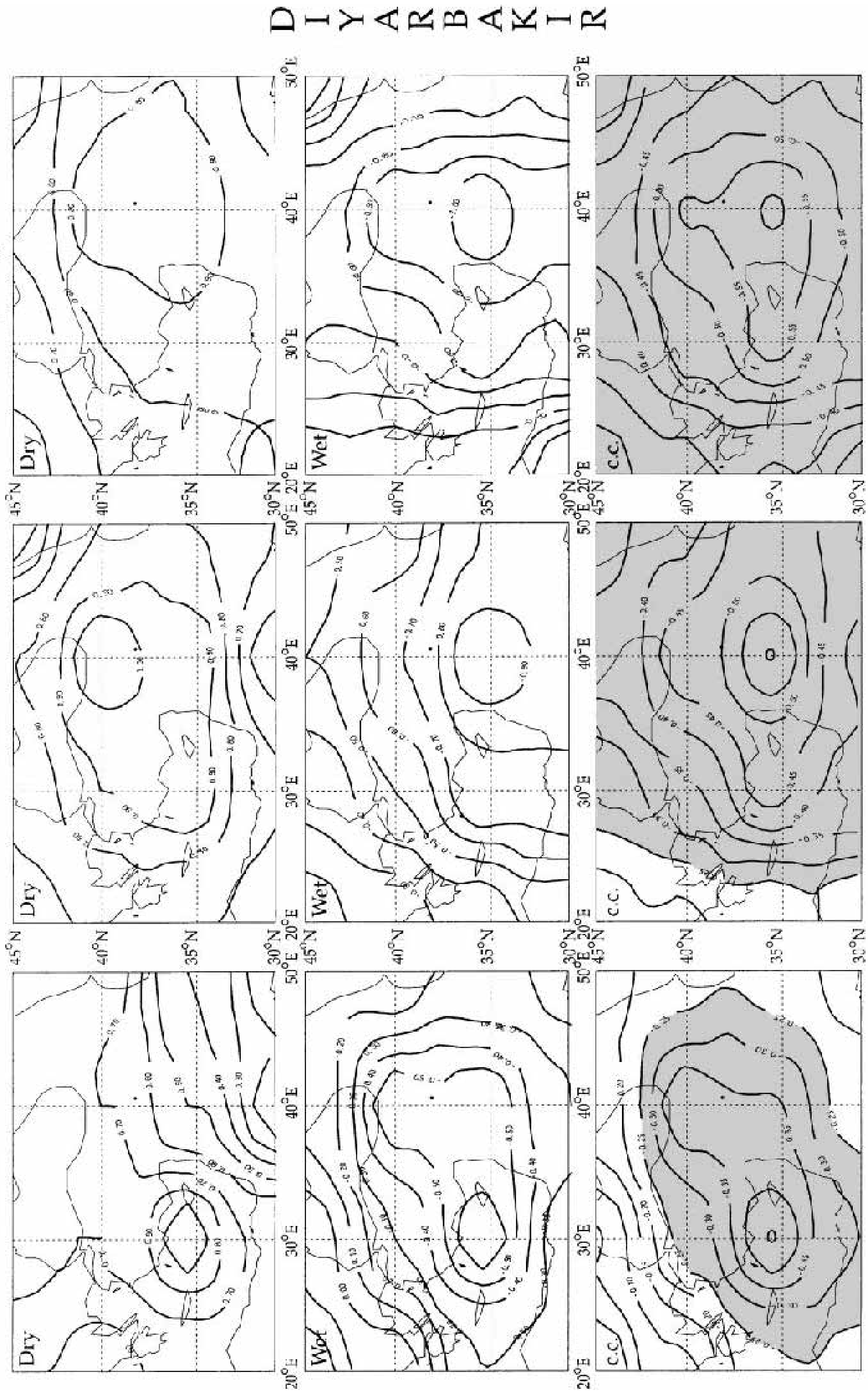

Fig. 11a. Same as Fig. 5a, but for Diyarbakir

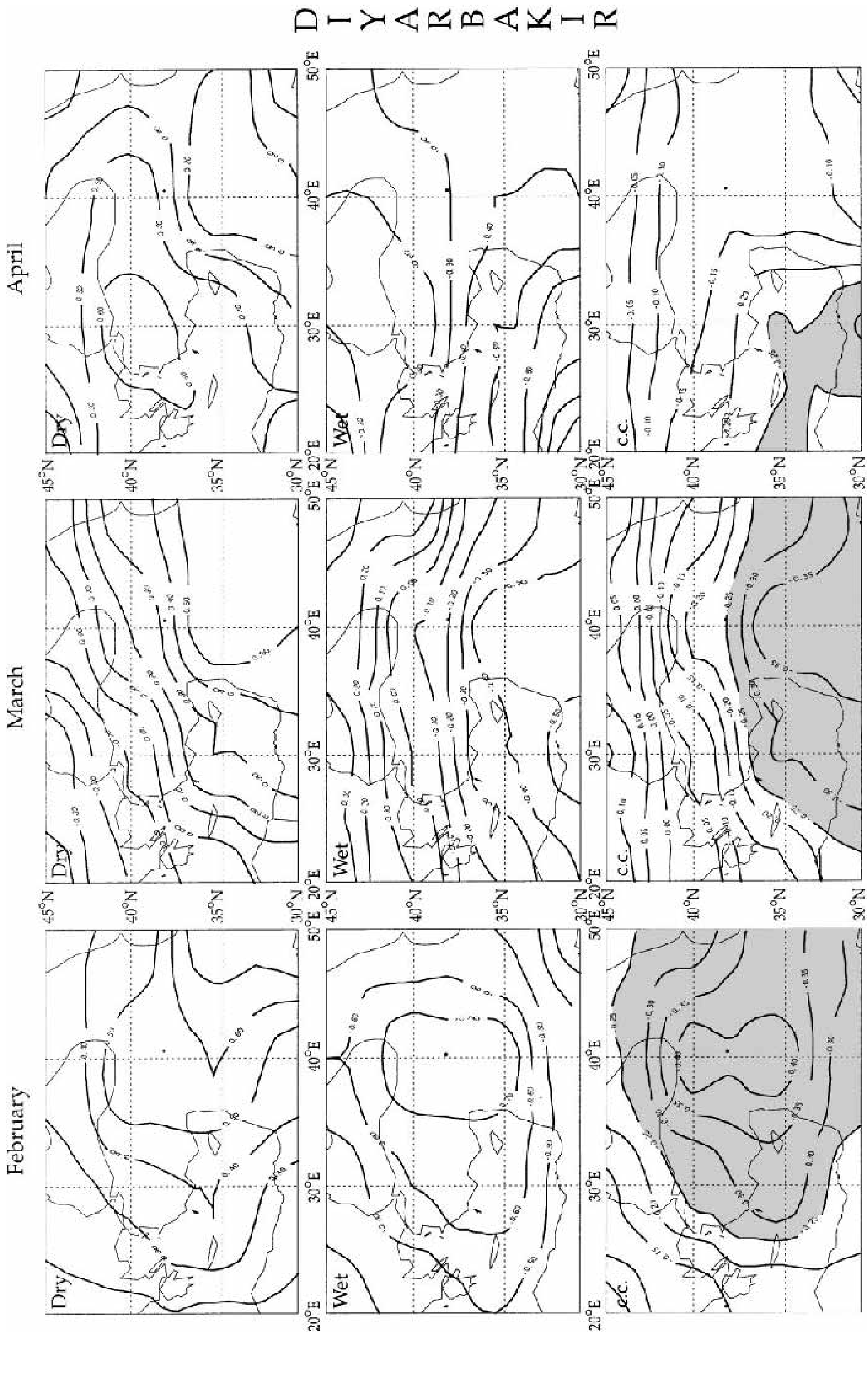

Fig. 11b. Same as Fig. 5b, but for Diyarbakir

activity. In spring and in autumn there are intermediate figures. Very similar results were reported also for Israel (Kutiel, 1982; Sharon and Kutiel, 1986; Kutiel, 1990) and there as well, the results were attributed to an increase in convective activity in the transitional seasons as compared to winter. For this reason, the discussion about the relationship between rainfall and pressure will be restricted only to the period November–April.

A general feature consisting positive SLP departures for *dry* conditions and negative SLP departures for *wet* conditions, was found. In other words, *dry* conditions are associated with above normal pressure conditions while *wet* conditions are associated with below normal pressure conditions. However, the spatial patterns and intensity of the departures vary from one station to another.

Figure 2, presents the SD of the pressure for each month, while, Figs. 5–11, present the standardized pressure departures for *dry* or *wet* conditions. Thus, a combination of these two sets of maps provides the actual pressure departures (in hPa) associated with *dry* or *wet* conditions at each of the analysed stations for every month in the period November–April.

3.2.1 Marmara Transition (Göztepe)

Pressure anomalies related to *dry* or *wet* conditions in Göztepe, demonstrate a mainly zonal distribution, with above normal SLP values over the Black Sea for *dry* conditions and below normal SLP values over that region for *wet* conditions. Precipitation totals in Göztepe are significantly correlated with SLP, from December to March. In November and in April no significant c.c. exist (Fig. 5a and 5b).

Dry or *wet* conditions in November are characterized only by slight pressure departures up to 0.4 SD (Fig. 5a).

Dry conditions in Göztepe in December are associated with considerable above normal SLP departures over the Black Sea (more than 1.2 SD) decreasing southwards and thus causing a southeastern anomaly flow towards Göztepe. *Wet* conditions, on the contrary, are characterized by below normal SLP values over the Black Sea, causing northerly anomaly flow towards that station. Correlation coefficients in December increase from southwest (over northern Egypt), where they are not significant, towards the northern part of the Caspian Sea with highest values greater than −0.45 (Fig. 5a).

Dry conditions in January are associated with a ridge of anomaly SLP covering most of the Balkans and Turkey. Anomaly values decrease either north, east or southwards. *Wet* conditions are characterized by below normal SLP conditions increasing northward. The correlation fields in this month, demonstrate a zonal pattern, with increasing values northwards over the Caucasus Mountains and the northern Caspian Sea. The highest values (−0.55) were obtained over northern Turkey and over the Black Sea (Fig. 5a).

The maps for February depict centres of positive (maximum +0.8 SD) or negative (maximum −0.9 SD) anomalies for *dry* and *wet* conditions respectively. These centres are located over Turkey extending from Crete to the Black Sea. The highest values in February are very similar to those found in January, but their location is different. In this month the highest values are located over Turkey, slightly increasing eastwards. No significant relationship between precipitation in Göztepe and SLP over northern Saudi Arabia, was found (Fig. 5b).

In March again, the patterns depicted by both anomaly maps for *dry* and for *wet* conditions, are very similar with opposite signs. The map depicting the anomalies associated with *dry* conditions, shows maximum positive anomalies (up to 0.8 SD) over Georgia, decreasing southwards, causing a southeastern anomaly flow over Göztepe. The map for *wet* conditions is almost identical with negative anomalies reaching a maximum of −1.0 SD over Georgia, which causes an opposite anomaly flow over Göztepe. In March the correlations patterns are somewhat similar to the correlations fields in December, increasing towards the Caucasus Mountains. However, the maximum c.c. are slightly greater (over −0.50), and the non significant area is also larger and comprises the southernmost part of the eastern Mediterranean Basin along with the north African and Levant coasts (Fig. 5b).

The anomaly map for *dry* conditions in April is very similar to the map for *dry* conditions in the previous month. Even the magnitude of the departures is similar and thus, also the anomaly flow. SLP departures associated with *wet* conditions are negligible and no recognizable pattern exist (Fig. 5b).

3.2.2 Black Sea (Giresun)

Among all stations analysed in the present study, Giresun, has shown the lowest number of significant correlations. Furthermore, while in the other stations, significant c.c. were all *negative* and located near the station or at least, over Turkey, in the case of Giresun, the significant c.c. are mainly *positive* and located near the edges of the study area. As mentioned earlier, positive correlation fields should be regarded as representing centres of high pressure and the derived circulation thus is clockwise. Unlike as with other stations, both *dry* and *wet* conditions at Giresun are associated mainly with above normal pressure conditions. However, the location, pattern and intensity of the increase in SLP, differs from one month to another.

In November, there are significant positive c.c. with the pressure over western Turkey, increasing towards the Balkans. This pattern is associated with a northerly circulation over the Black Sea towards northern Turkey (Fig. 6a). Apart from November, only in March there are significant c.c. which are relevant to precipitation in Giresun: negative c.c. over the northeastern part causing again a northern to northwestern circulation from the Black Sea towards northern Turkey (Fig. 6b). In all other months there are very few significant c.c. However, although not significant, the derived circulation towards Giresun, associated with precipitation, is from the Black Sea in all months (Fig. 6a and 6b).

Dry Novembers are characterized by a meridional pattern of SLP departures. Significant positive SLP anomalies are found in the region that is east of Turkey, while negative departures dominates over the Balkans. These pressure anomaly patterns, which are characterized by the cyclonic circulation at the west and the anticyclonic circulation at the east of the study area, cause a southerly air flow over Turkey that creates a foehn effect along the eastern Black Sea coastal belt of Turkey. *Wet* conditions are developed by large positive departures over the Balkans and normal conditions over eastern Turkey. Resultant north to northeastern anomaly flow over Turkey of this characteristic anomaly pattern causes an orographic rise of air masses above the high eastern Black Sea Mountains. This orographic originated rainfall makes a considerable contribution to autumn and winter rainfall amounts, in addition to the contribution of the frontal mid-latitude depressions that are frequent and effective in these seasons over the region (Fig. 6a).

The anomaly maps for *dry* or *wet* conditions in December are similar with opposite signs. Thus, dry conditions are characterized by positive departures over eastern Turkey and the Caspian region and normal conditions over western Turkey. *Wet* conditions are characterized by above normal SLP values over the Balkans and normal conditions over eastern Turkey. In both cases the maximum departures are not large, about 0.4 SD above normal (Fig. 6a).

In January, *dry* conditions are characterized by a centre of positive anomalies located over eastern Turkey. *Wet* conditions are characterized by slight negative anomalies over the Caspian and northern Iran (Fig. 6a).

In February, again the maps depicting pressure departures for *dry* or *wet* conditions are similar with opposite signs. *Dry* conditions are characterized by above normal SLP conditions over the Caspian Sea and below normal SLP over the Balkans. The departures for *wet* conditions are opposite, negative over the Caspian and positive over the Balkans (Fig. 6b).

In March, we can observe a southwest-northeast gradient of pressure departures for both *dry* and *wet* conditions. *Dry* conditions are characterized by large positive anomalies (more than 1.2 SD) over the Caspian and the adjacent region, decreasing constantly towards Libya, causing a southeastern anomaly flow over Giresun. The anomaly map for *wet* conditions, depicts large positive anomalies (up to 1.2 SD) over Libya, decreasing towards the Caspian Sea, causing a northwesterly anomaly flow over Giresun (Fig. 6b).

SLP departures for *dry* conditions in April, depicts a similar pattern as in the previous month, but with much smaller departures (about 0.5 SD). *Wet* conditions are associated with below normal SLP over the Caspian region (Fig. 6b).

3.2.3 Mediterranean (Muğla)

Correlation fields related with rainfall in Muğla, tend to depict a more meridional pattern with c.c. decreasing eastward. The highest c.c. are observed mainly over western Turkey and/or the Aegean

Sea. Due to its location, in the western part of Turkey, SLP anomalies associated with either *dry* or *wet* conditions in Muğla, tend to be more important over western Turkey. As expected, dry conditions are related to positive anomalies, while wet conditions to negative anomalies.

In November, *dry* conditions are characterized by above normal SLP over Turkey, with the maximum anomalies (up to 0.9 SD) over the western part of the country. *Wet* conditions are associated with below normal pressure conditions, again more evident over western Turkey. Correlation fields are significant over most of the study area, excluding the easternmost regions of Saudi Arabia, Iraq and parts of Iran. The highest values were obtained for the western part of Turkey. The c.c. over this region exceeded −0.50 (Fig. 7a).

Anomaly maps for December and January are very similar, either for *dry* or *wet* conditions. However, departures in January are slightly greater than in December. *Dry* conditions are characterized by large positive anomalies (1.0 SD in December and 1.4 SD in January) over the Balkans, northern Aegean and the Marmara regions causing easterly to northeasterly anomaly flow over Muğla. *Wet* conditions are associated with below normal conditions over western Turkey and Greece. Correlation fields in December, are significant almost all over the study area. Correlation coefficients decrease eastwards. The highest values are slightly higher than in the previous month (greater than −0.60) and located further west over the Aegean and Greece (Fig. 7a).

In January, all c.c. over the entire study area are statistically significant. Correlation values decrease southeastwards. The highest c.c. (greater than −0.80), which is also the highest c.c. found between precipitation and SLP, of any station included in the present study, is located over the Sea of Marmara (Fig. 7a). This can be attributed to the fact that winter rainfall over the western and southernmost regions of Turkey are associated closely with the northern Atlantic and the Mediterranean originated depressions (Türkeş, 1998).

In February, unlike in other cases, the maps depicting SLP associated with *dry* or *wet* conditions are not similar with opposite signs, but rather completely different. The map showing the anomaly pressure associated with *dry* conditions, depicts a meridional pattern of positive anomalies greater than 1.1 SD, over Greece and western Turkey, decreasing eastwards. *Wet* conditions are associated with negative anomalies, mainly over northwestern Turkey and the Black Sea. In February, the correlation fields depict again a meridional pattern decreasing eastwards. The highest c.c. were found to be over western Turkey, the Aegean and over Greece with values greater than −0.55 (Fig. 7b).

Dry conditions in March are associated with above normal pressure (up to 0.6 SD) over Georgia and northeastern Turkey. *Wet* conditions are associated with below normal pressure (up to −0.7 SD) over Greece and western Turkey. In March and April there is a reduction both in size and in correlation values of the significant correlation fields as compared with the previous months. The highest correlations are located over northwestern Turkey, northern Aegean and northern Greece with maximum values of −0.40. Correlations with the northeastern and southeastern corners of the study area are not significant (Fig. 7b).

In April, the maximum pressure anomalies for either *dry* or *wet* conditions are located over Greece. *Dry* conditions are associated with above normal SLP values over Southern Greece and Crete, while *wet* conditions are associated with below normal values over northern Greece. The highest correlations are over the southern part of the Marmara Transition region and the south half of the Sea of Marmara with values of −0.35. Correlation with all countries located southeast of Turkey are not significant (Fig. 7b).

3.2.4 Mediterranean to Central Anatolia Transition (Uşak)

Correlation fields of precipitation and SLP for Uşak are generally very similar to those for Muğla, because these two stations are located over the Mediterranean type rainfall regions that are differentiated with each other slightly. The highest c.c. are slightly lower as compared to those in Muğla in November, December, January and April, and slightly greater in February and March. There is also a great degree of similarity between patterns associated with *dry* or *wet* conditions in Uşak with those associated with the same conditions in Muğla. Dry conditions tend to be associated mainly with above normal pressure over the Balkans.

Dry conditions in November are associated with above normal pressure conditions over the entire study area. The maximum positive departures were found over the Sea of Marmara and the adjacent region, with values of over 0.9 SD. The derived anomaly flow over Uşak is mainly easterly. *Wet* conditions are associated with below normal pressure values mainly over western Turkey and the region between Crete and Cyprus over the Mediterranean (Fig. 8a). Significant correlation fields in November cover most of the study area, including all Turkish territory, the Black Sea, the Aegean Sea and the Mediterranean Sea, and the Balkans. The highest c.c. (greater than −0.40) is obtained with SLP over western Turkey. SLP over the countries southeast and east of Turkey, is not significantly correlated with precipitation in Uşak.

In December, *dry* conditions are related to major positive departures over the entire study area. Over the Balkans, one can find the greatest departures (more than 1.3 SD), causing a significant easterly or northeasterly anomaly flow over Uşak. Below pressure values over all the study area characterize the pressure conditions associated with *wet* conditions. The greatest departures are found over Greece (−0.9 SD), causing a southerly anomaly circulation over Uşak. In December, SLP over almost all the study area is significantly correlated with precipitation in Uşak. Correlation values increase westwards. The highest c.c. (greater than −0.55) are found over Greece (Fig. 8a).

Pressure departures in January are even larger than in the previous month. *Dry* conditions are associated again with above normal pressure values mainly over the Balkans and northwestern Turkey, up to 1.4 SD. *Wet* conditions are associated with a SLP departure of up to 1.0 SD below normal over western Turkey and parts of Greece. In January, SLP over all the study area is highly correlated with precipitation in Uşak. The highest c.c. (greater than −0.75) are found mainly over northwestern Turkey (Fig. 8a). It is worthwhile to compare with correlation fields of Muğla in January (Fig. 7a) and note the great resemblance between the two.

Dry conditions in February are related with positive departures over the Balkans, however, reaching smaller values as compared with previous months (maximum 0.7 SD). *Wet* conditions occur when there are negative anomalies over the same area causing a southwesterly anomaly flow over the station. The highest c.c. in February are found over the Sea of Marmara with values greater than −0.65. Correlations' values decrease rapidly east and southwards. SLP over northern Saudi Arabia is not significantly correlated with precipitation in Uşak (Fig. 8b).

In March, there is a positive pressure departure of up to 0.5 SD over most of Turkey associated with *dry* conditions in Uşak. *Wet* conditions are related with a major negative pressure anomaly over all the study area. The greatest anomaly (more than −1.0 SD) is found over western Black Sea and northwestern Turkey. The correlation patterns for March are very similar to the previous month, including the location of the highest c.c. However, in March, c.c. over Turkey are slightly lower than in February, while c.c. with regions east or south of Turkey, are slightly, higher (Fig. 8b).

Finally, in April *dry* conditions are associated with a positive pressure anomaly over southern Greece, while *wet* conditions with a negative anomaly over the same region (Fig. 8b). In April, SLP over most of the study area is not significantly correlated with precipitation in Uşak. This relatively weaker relationship may have arisen from somewhat continental character of this respectively inner region, which results local convective rainfall events in spring and early summer over the area of Uşak station. Significant correlations are found only over western Turkey, Greece and the Mediterranean with highest values not exceeding −0.25 (Fig. 8b).

3.2.5 Continental Central Anatolia (Ankara)

Dry conditions in Ankara are associated with above normal pressure over Turkey, while *wet* conditions are associated with below normal pressure conditions. Correlation fields associated with rainfall in Ankara depict a common pattern in all months from November to March: significant negative correlations over most of the study area with the highests values (−0.40 to −0.60) over northern Turkey or over the Black Sea. In April c.c. are lower (−0.30) and are significant over the eastern study area.

Dry Novembers are characterized by above normal SLP over all the study area, with a maximum of 0.9 SD covering the entire territory of Turkey. *Wet* conditions in this month are characterized by below normal SLP mainly over northeastern Turkey and the Caucasus. Correlation fields in November are significant over most of the study area, except, northwestern part of the Balkans and northern Saudi Arabia. There is a centre of negative c.c. that covers most parts of Turkey. The c.c. values are about −0.40 (Fig. 9a).

Dry Decembers in Ankara are characterized by above normal pressure greater than 0.8 SD, mainly over the northern and western regions of Turkey, and over the Balkans. The pressure increase is less evident over the southeastern part of the study area, namely over Israel and Jordan. *Wet* conditions in this month are related with below normal pressure values, which vary between −0.6 SD and −0.7 SD, over western Turkey and over the Aegean Sea and Greece. In December, c.c. over almost all the study area, are significant except the southeastern corner. Correlation coefficients over the western and northern regions of Turkey are about −0.45 (Fig. 9a).

Dry Januarys are characterized by over one SD above normal pressure conditions, mainly over northern Turkey. *Wet* Januarys are characterized by about 0.7 SD below normal pressure conditions over the entire territory of Turkey. In January, all c.c. are significant at the 0.05 significance level. The highest c.c. are obtained over northern Turkey and the Black Sea with values of −0.60 (Fig. 9a).

In February, *dry* conditions are characterized by a rise in pressure by over 0.5 SD, with a maximum of 0.6 SD over the Sea of Marmara. *Wet* conditions are associated with below normal pressure conditions over the entire territory of Turkey with the maximum decrease of −0.6 SD over northeastern Anatolia and the eastern Black Sea subregions of Turkey. In February most of the c.c. are significant. The highest c.c. are greater than −0.40, crossing the northern parts of Turkey. Correlation with pressure over the southeastern part of the study region including, Israel, Jordan, Syria and parts of Egypt and Iraq are not significant (Fig. 9b).

In March, *dry* conditions are associated again with above normal conditions up to 0.9 SD. The maximum raised in SLP is observed over northeastern Turkey. *Wet* conditions in March demonstrate a zonal pressure decrease with a maximum of more than one SD over the Black Sea. The correlation fields for March are very similar to those of February with the exception that in March values are higher (the maximum is greater than −0.55) and almost all the area is significant (except the northern bound of Saudi Arabia (Fig. 9b).

Finally, in April the decrease of the dependence of the rainfall on the regional pressure patterns, shown in Fig. 4, is reflected by small pressure departures either for *dry* or *wet* conditions. *Dry* conditions are characterized by a slight increase of SLP mainly over eastern Turkey. *Wet* conditions are characterized by below normal SLP values over the southern part of the study area (Libya, Egypt, Israel and Jordan). In April, c.c. are much lower as one could expect. The highest values are around −0.30. The spatial distribution is also different as compared to other months. Correlations are not significant over the Balkans and the Aegean (Fig. 9b).

3.2.6 Continental Eastern Anatolia (Sarikamiş)

Due to its location in eastern Turkey, most of the significant correlation fields and highest c.c. tend to be located over the eastern part of the study region. Furthermore, *dry* conditions in Sarikamiş, are associated with SLP departures mainly over eastern Turkey and eastwards. However, *wet* conditions are related to pressure departures over various regions in the different months.

In November, *dry* conditions are associated with above normal SLP values by more than 0.5 SD, over the Caspian region. This anomaly, causes a southerly anomaly flow over Sarikamiş. *Wet* conditions are associated with below normal pressure over the Mediterranean between Crete and Cyprus. The highest correlations were found to be located in the vicinity of the Caspian Sea with values greater than −0.30. There is a trough of significant correlation extending westwards covering Cyprus. The rest of the study area, including most parts of Turkey are not significant (Fig. 10a).

Pressure anomalies related to *dry* conditions in December, depicts a similar pattern as in the previous month. However, the departures are larger as compared with November's departures. Over all northeastern Turkey, Georgia and the Caspian region, SLP departures are over 1.0 SD. The derived anomaly flow over Sarikamiş is southeastern. *Wet* conditions, are associated with a general negative pressure anomaly of about −0.6 SD over most of the study area without any definable pattern. In December, SLP over almost all the region is significantly correlated (negatively) with precipitation in Sarikamiş. The highest c.c. are located over eastern Turkey, northern Iraq and northern Iran (Fig. 10a).

In January, *dry* conditions are associated with a clear positive pressure anomaly over the entire study area. The maximum anomaly, with values of 0.7 SD, is found over the northeastern corner of the Mediterranean including Cyprus, and over the Mediterranean, south-eastern and eastern regions of Turkey. Anomalies related to *wet* conditions depict a pattern similar to that for November, but with larger anomalies. Thus, the greatest anomalies are found over the eastern Mediterranean between Crete and Cyprus, up to −1.0 SD. In January, correlation are significant over all the study area. The highest correlations (greater than −0.45 were found in an ellipse shape area extending from eastern Mediterranean northeast towards the Black Sea (Fig. 10a).

Dry conditions in February are associated with a general positive pressure anomaly, over the entire study area. This anomaly increases eastwards and reaches its maximum value (1.0 SD) over northern Syria and northern Iraq. The derived anomaly flow over Sarikamiş is mainly southerly. *Wet* conditions are associated with below normal pressure values over the entire region with the maximum anomaly (−0.9 SD) over northwestern Turkey. Correlation fields in February, are similar to the previous month with some reduction in c.c. values. The highest c.c. of −0.40 are found over all parts of Turkey (Fig. 10b)

In March, both, *dry* and *wet* conditions are associated with SLP departures mainly over the easternmost part of the study region. *Dry* conditions are associated with departures, up to 0.6 SD over northern Iran, causing a southeasterly anomaly flow over Sarikamiş. *Wet* conditions are associated with negative pressure departures of the same order of magnitude, centered mainly over northern Syria and northern Iraq, causing an easterly anomaly flow. The correlations between SLP and precipitation in Sarikamiş are significant only over central and southeastern part of the study area. This includes all parts of Turkey and the neighboring countries to the southeast. Correlation with most of the Black Sea, Aegean and the Balkans are not significant. The highest c.c. are located over Syria with values of −0.45 (Fig. 10b).

Dry conditions in April, depict a similar pattern as in the previous month. However, *wet* conditions in this month, are associated with an important negative pressure anomaly over Crete and southern Greece extending towards Turkey. The SLP over most of the study area is significantly correlated with precipitation in Sarikamiş. However, c.c. are rather small. Most c.c. are around −0.25 with the highest values around −0.30, located mainly over Greece and southwest Anatolia (Fig. 10b).

3.2.7 Continental Mediterranean (Diyarbakir)

Dry conditions in Diyarbakir are associated with above normal pressure mainly over southeastern Turkey, northern Syria and northern Iraq, while *wet* conditions are associated with below normal pressure conditions mainly over the southern and eastern regions of Turkey, Lebanon, Israel and Cyprus. Correlation fields associated with precipitation in Diyarbakir tend to be located over southern or eastern Turkey for the period from November to March. In April the only significant region is located over the southwestern part of the study area, mainly over the eastern Mediterranean Basin. Correlation coefficients in Diyarbakir are slightly smaller than in Ankara.

Dry Novembers are characterized by above normal SLP mainly over the Mediterranean between Crete and Cyprus. SLP over this region is higher than normal by more than 0.9 SD. *Wet* conditions in this month are associated with below normal SLP over all regions of Turkey with the main decrease over the Mediterranean, again between Crete and Cyprus, with values reaching 0.6 SD or more, below average. In November, the significant correlation fields have an ellipse like shape extending from North African coasts of Libya and Egypt, including Israel, Lebanon, Jordan, Syria, Iraq and almost all the Turkish territory but not the Black Sea. The highest c.c. values (greater than −0.40) are located over mid of the eastern Mediterranean, the Mediterranean coast of Turkey and west of Cyprus (Fig. 11a).

Dry Decembers in Diyarbakir are characterized by above normal pressure (greater than 1.0 SD above average) mainly eastern Turkey with the eastern Black Sea sub-region. *Wet* conditions in this month are related with below normal pressure values over all regions of Turkey with the maximum decrease over northern Syria. In December, almost all the region is significantly correlated with precipitation in Diyarbakir, except a narrow strip extending from north to south on the westernmost part of the study area. Correlation values in December are larger than in the previous month with a maximum around −0.60. However, unlike in November, the location of the highest c.c. is over northern Syria and not over the Mediterranean (Fig. 11a).

Dry Januarys are characterized by 0.9 SD above normal pressure conditions, over eastern Turkey, northwestern Syria and Lebanon. *Wet* Januarys are characterized by more than 0.9 SD below normal pressure conditions over the eastern Turkey, Syria, Lebanon, Israel and Jordan. The spatial pattern of the correlation fields in January are very similar to the pattern in December. The maximum c.c. is located over the same region and the values are very alike. The only difference with the previous month is that all correlations are significant (Fig. 11a).

In February, *dry* conditions are characterized by a rise in pressure over eastern Turkey and northern Iraq. *Wet* conditions are associated with below normal pressure conditions over the entire territory of Turkey with the maximum decrease of 0.7 SD over southeastern Turkey and northern Syria. In February, there is a reduction in the extent of the region with significant c.c. This region includes only Turkey and the areas located south and east of Turkey. Most of the Black Sea, the Balkans and the North African coast are not significant. The highest correlations are lower than in previous months and located over eastern Turkey, north of their location in the previous months (Fig. 11b).

Dry conditions in March, in Diyarbakir are associated with above normal conditions up to 0.5 SD over parts of Syria and northern Iraq and southeastern Turkey and below normal pressure over the Balkans. The pressure patterns associated with *Wet* conditions demonstrate a zonal distribution, i.e., above normal over the Black Sea and the Balkans, normal or slightly below normal over Turkey and below normal over the southeastern Mediterranean coast and over Egypt. The correlation fields in March have a very clear zonal orientation. Correlation values decrease from north to south. Correlation values are significant only over Iraq, Syria, Jordan and Israel with values not exceeding (−0.35, Fig. 11b).

In April *dry* conditions in Diyarbakir are associated with above normal pressure conditions over all parts of Turkey with the maximum departures over western Turkey (more than 0.6 SD above normal). *Wet* conditions are associated with considerable below normal pressure conditions over the African coasts of the eastern Mediterranean and mainly over Libya and Egypt. Correlations in April are not significant except from a small region in the southwestern corner of the map, mainly over the sea. Although, this region is significant, its relevance to the rainfall in Diyarbakir is not clear (Fig. 11b).

The above results revealed a tendency of eastward displacement of the central location of the positive pressure departures associated with *dry* conditions, from November to April. Similarly, there is a tendency northeastward of the pressure patterns associated with *wet* conditions. Both tendencies reflect an eastward (northeastward) movement of the main centres of action in that region. Very similar tendencies were obtained by Kutiel and Paz (1998) in their analysis regarding pressure patterns associated with dry or wet conditions in Israel.

4. Conclusions

The results of the present study, leads to the following conclusions:

1–The variability of the SLP in the eastern Mediterranean region, demonstrates a clear spatial and temporal pattern. The variability decreases from the Balkans towards the Arabian Peninsula and is much larger in winter as compared with summer over most parts of the study area.

2–The relationship between rainfall in Turkey and the regional SLP distribution has a clear seasonal course. In winter, rainfall over most regions in Turkey, is highly depending on SLP, while in summer, no such relationship exists.

3–Pressure pattern associated with *dry* or *wet* conditions in each station, are distinguishable each other. Pressure patterns associated with *dry* conditions, show usually positive SLP departures, whereas, pressure values associated with *wet* conditions are usually below normal.

4–There is a great resemblance between pressure patterns associated with *wet* conditions and correlation maps. This, increase our confidence in the results.

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