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Monthly Synoptic Patterns Associated with Wet/Dry Conditions in the Eastern Mediterranean

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With 10 Figures

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Summary

An investigation of the main features of large-scale synoptic patterns over Europe and the adjacent areas for extreme winter periods during 1980–1995 over the Eastern Mediterranean (EM) is performed. The NASA reanalysis data set is used to investigate composite sea level pressure (SLP), geopotential height of the 500 hPa surface (H-500) and precipitation – wet, normal and dry patterns for each month during the period October–March. It is found that the wet and dry cool seasons in the EM are associated with distinct SLP and H-500 anomaly patterns over Europe and the adjacent regions. During the dry spells large-scale positive SLP/H-500 anomaly areas prevail over Eastern Europe. A negative SLP anomaly is normally found during these periods over southwestern and Western Europe. During the wet cool seasons in the EM there are mainly negative SLP/H-500 anomaly areas over Eastern Europe to the north east of the EM. Positive SLP/H-500 anomalies are found over Western Europe.

During wet months a trough zone between the Siberian and the Azorean Highs is positioned over the eastern part of the Mediterranean. During dry months the Siberian anticyclone is more intensive and the zone with low surface pressure is displaced to the central part of the northern Mediterranean.

1. Introduction

The Eastern Mediterranean (EM) region is located in the area where both the mid-latitude and equatorial atmospheric processes play major roles during the rainy season. This complicates weather prediction to any range. The role of mid-latitude processes has been widely recognized (Illani, 1998; Krown, 1966; Peterssen, 1956; Reiter, 1975) and importance of tropical processes has also been stressed. For instance, Krishnamurti (1960) highlighted the specific role of the upper-tropospheric subtropical jet stream (STJ) in this region and the role of equatorial area convective processes (Krishnamurti et al., 1973). The role of processes in tropical Africa has been demonstrated recently by Krichak and Alpert (1998). The development of the Red Sea Trough (Ashbel, 1938; Izikson, 1997; Krichak et al., 1997a,b), appears to be one of the most impressive manifestations of the mid-latitude–equatorial area interactions in the Mediterranean region.

The rainy season in the EM normally lasts from October to April. In the summer months rainfall is a rare occurrence in the EM due to the predominance of the quasi-permanent subtropical high system (Alpert et al., 1990a). Analysis of the cyclone tracks in the Mediterranean area made by Alpert et al. (1990a,b) shows that in normal and wet years the region is characterized by higher frequencies of cyclone tracks. The situation is different during the dry periods when the tracks occur over other areas. Recent findings prove that the air masses from the Arabian Sea also play a role in the EM circulation (Krichak and Alpert, 1998).

Sea Level Pressure (SLP) departures from normal over the Mediterranean and adjacent region and their relationship with monthly rainfall in Israel were recently analyzed by Kutiel and Paz (1998). The study was based on application of climatological data and the rainfall data measured at 12 stations in Israel. The study identified the pressure patterns associated with dry or wet conditions for each month during the rainy season in Israel. The study delimited regions in Israel that are affected by different pressure variations in each month. This current study uses a similar method to Kutiel and Paz, but is focused on a different location.

The purpose of the study is as follows: (a) to determine the Eurasian pressure patterns which are associated with dry or wet conditions over the EM (b) to evaluate the relationship between the precipitation in Israel and the mean EM monthly averaged rainfall. Composite anomaly patterns of the SLP, geopotential height of the 500 hPa (H-500) isobaric surface and precipitation patterns for each month of the rainy season in the EM are considered.

Investigation of the large-scale synoptic patterns over Eurasia for typical wet and dry months in the EM is useful for understanding the mechanisms responsible for the differences in cyclone orientation and frequencies. Recently Ben-Gai et al. (1999) demonstrated that relationships between the EM and Atlantic processes are manifested by a high correlation of .9 between the North Atlantic Oscillation (NAO) index and the pressure anomaly over Israel. The physical mechanism for this relationship has not yet been fully investigated. An additional motivation for such an analysis is the requirement for a longer scale prediction of precipitation. The amount of precipitation over a particular relatively small area in the EM (like Israel) is not necessarily the optimal choice for representation of the area averaged precipitation over the whole EM region. This evident fact may be significant for seasonal forecasting, and in particular, for the verification of its efficiency. Even a slight shift in the actual large-scale pattern versus that predicted would convert a sufficiently accurate prediction to an unsuccessful one if the adopted method of verification ignores this fact. Statistical approaches which formally allow determination of the expected future conditions over only a small area, are of limited use (Mandel, 1994a,b). Accurate prediction of the existence of typical SLP anomaly patterns over Europe for wet (dry) EM months may possibly be useful for improving the accuracy of long-range forecasting in the area. Improved knowledge of such patterns may be also useful for the investigation of potential climatic changes in the 21st century.

2. Selection of Data for the Composite Atmospheric Patterns

The work is mainly based on the application of 15-year NASA reanalysis data set for the 1980–1995 period (Schubert et al., 1993). A relatively small area of 31° N–35° N; 34° E–37° E is selected to represent the EM region. The area averaged, model generated precipitation values are determined for each month during the October–March period (see Table 1). The results based on part of the data for the period from 1980 to 1990 are shown in Fig. 1 by a deep solid line with circles. The other five graphs on the figure represent the observed monthly precipitation for five regions in Israel – the west-north, east-north, west-center, east-center and the southern sub-regions. All these lines appear to be

Table 1. *Area Averaged Monthly Mean Precipitation over the Central-Southern Eastern Mediterranean (mm). Bold with Underlining – Wet EM Months; Bold Without Underlining – Dry EM Months*

Y's	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95
O	**5**	**6**	10	10	17	20	***44***	***59***	35	27	17	21	**8**	6	22
N	**4**	37	52	32	41	16	***71***	**11**	29	41	14	38	26	11	***84***
D	41	25	37	24	27	27	48	69	***74***	33	**13**	***87***	67	**9**	49
J	37	36	36	43	35	31	47	67	48	**26**	59	57	***79***	***84***	**29**
F	38	49	60	**18**	59	41	45	***90***	34	49	**32**	***91***	50	64	42
M	29	41	34	40	**13**	**11**	61	***68***	42	30	***68***	19	32	41	14
A	13	16	26	***33***	22	16	**9**	***27***	**4**	26	23	10	19	18	16

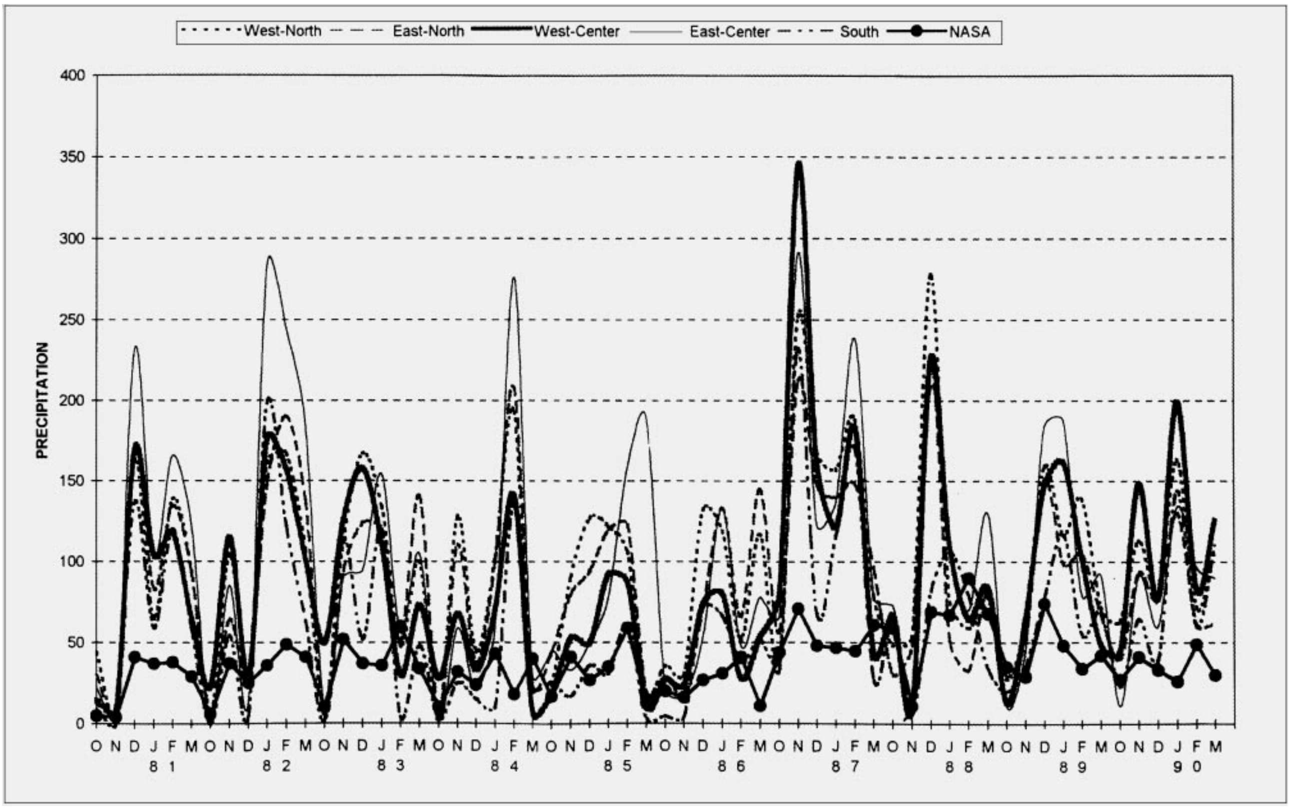

Fig. 1. Monthly mean precipitation amounts (mm) during October–March period (1980–1990) for few Israel sub-domains (west-north, east-north, west-center, east-center and south) from the observations and for the Eastern Mediterranean region from the NASA reanalysis

similar in their main features. Correlation analysis made separately for these five sub-regions versus the NASA model generated EM monthly rains give the following values for the correlation coefficients: 0.41 (west-north); 0.39 (east-north); 0.48 (west-center); 0.42 (east-center) and 0.42 (southern). According to the values of the coefficients, the averaged re-analyzed data for the chosen EM area has the highest correlation with the observed monthly precipitation over the western part of the central Israel (deep solid line without the circles).

The area averaged model-generated values are significantly lower than the observed ones. This discrepancy is a consequence of different influencing factors but, primarily due to the differences in the horizontal scales of both types of data.

The data presented in Table 1 are used for selection of the periods with typical precipitation regimes over the EM. Averaged meteorological patterns for these periods are analyzed in the following section. The analysis will mainly focus on the composite synoptic large-scale patterns constructed according to the selections based on Table 1.

3. Composite Anomaly Patterns for Specific EM Precipitation Conditions

Averaged SLP and H-500 anomaly and precipitation patterns are determined for dry, normal and wet periods in the EM area. The October–March months of the data set were sub-divided into three 5-year groups according to the area-averaged precipitation in the EM (Table 2). Ranges of precipitation in each of the groups are given in Table 3. During the same time periods the years chosen for each of the categories do not exactly coincide with those selected by Kutiel and Paz (1998). This is mainly a consequence of the significant difference in the method of area averaging of the rainfall data.

The 5-year averaged mean-monthly SLP and H-500 anomaly patterns are then constructed. The SLP and H-500 anomaly patterns (*current*

Table 2. *Years Representing Specific Precipitation Periods in the Eastern Mediterranean*

	Oct	Nov	Dec	Jan	Feb	Mar
Dry	80,81,82, 92,93	80,87,85, 90,93	81,83,84, 90,93	82,85,86, 90,95	81,84,86, 89,91	81,85,86, 92,95
Med	83,84,85, 90,91	81,83,88, 91,92	80,82,85, 86,89	81,83,84, 87,89	82,87,90, 93,95	83,84,90, 93,94
Wet	86,87,88, 89,94	82,84,86, 89,94	87,88,91, 92,94	88,91,92, 93,94	83,85,88, 92,94	82,87,88, 89,91

Table 3. *Amount of Precipitation (mm) Representing Each Type of Precipitation Regimes*

	Oct	Nov	Dec	Jan	Feb	Mar
Dry	0–10	0–16	0–27	0–36	0–41	0–29
Medium	11–21	26–38	28–48	37–48	42–50	30–41
Wet	22–89	39–84	49–87	49–84	51–91	42–68

minus normal) are computed for each of the typical periods. They are presented in Figs. 2 and 3; for the wet, in Figs. 4 and 5 for the medium and Figs. 6 and 7 for dry periods in the EM.

The average SLP and H-500 anomaly patterns computed for the wet EM years possess the following main features (Figs. 2, 3). The area to the northeast of the EM is mainly covered by negative SLP and H-500 anomalies. In the case of October, December and March (Figs. 2, 3a,c,f), the EM region itself is located under the areas with the negative SLP and H-500 anomalies. Another area with negative SLP and H-500 anomalies is often found over the eastern Atlantic (See Fig. 3b,d,e,f). Western Europe is covered by areas with positive anomalies of SLP/H-500.

Patterns for the periods with medium (normal) EM precipitation look quite different. Negative SLP and H-500 anomaly areas are also found in the vicinity (to north-east) of the EM area (with the exception of the SLP January pattern – Fig. 4d). The centers of the areas are mainly located over the northern part of Europe, i.e. approximately over the area where the positive anomalies are found during the patterns associated with wet months. This feature is especially well demonstrated by the corresponding H-500 anomaly patterns for October, November, January, February and March (Figs. 3a,b,d–f and 5a,b,d–f).

The SLP and H-500 anomaly patterns for the dry EM months (Figs. 6, 7a–f) differ from those discussed earlier. In this case the southwestern and/or western part of Europe is located in an area with negative SLP and H-500 anomalies. Parts of the EM and further northeast are located in the area with a positive anomaly. Conditions over central and Eastern Europe are characterized by mainly positive SLP and H-500 anomalies. The H-500 patterns (Fig. 7a–f) represent these main features even better than those of the SLP. The EM is located in the area with the mainly southeastern mean surface dry airflow from southern Asia. During the dry EM periods the northern Mediterranean region is positioned under the area of negative SLP anomalies which suggests a tendency for an increase in precipitation.

In addition, the SLP anomaly patterns for extreme dry and wet months were also analysed (but not presented here). Each of these patterns was computed for only two years with extremely high or low precipitation determined according to Table 1. The patterns were found to be quite similar to those already discussed.

The existence of different patterns typical for those of the wet and the dry regimes can also be found in the precipitation data. The overall interdependency of the precipitation conditions over the EM and the northern Mediterranean is given in Fig. 8. Here the EM precipitation values (in the deviations from normal values) are plotted together with the mean monthly precipitation over a region of the northern Mediterranean (40° N–44° N; 10° E–13° E). The correlation coefficient computed for the two series yields a negative value -0.44. Accordingly, periods with

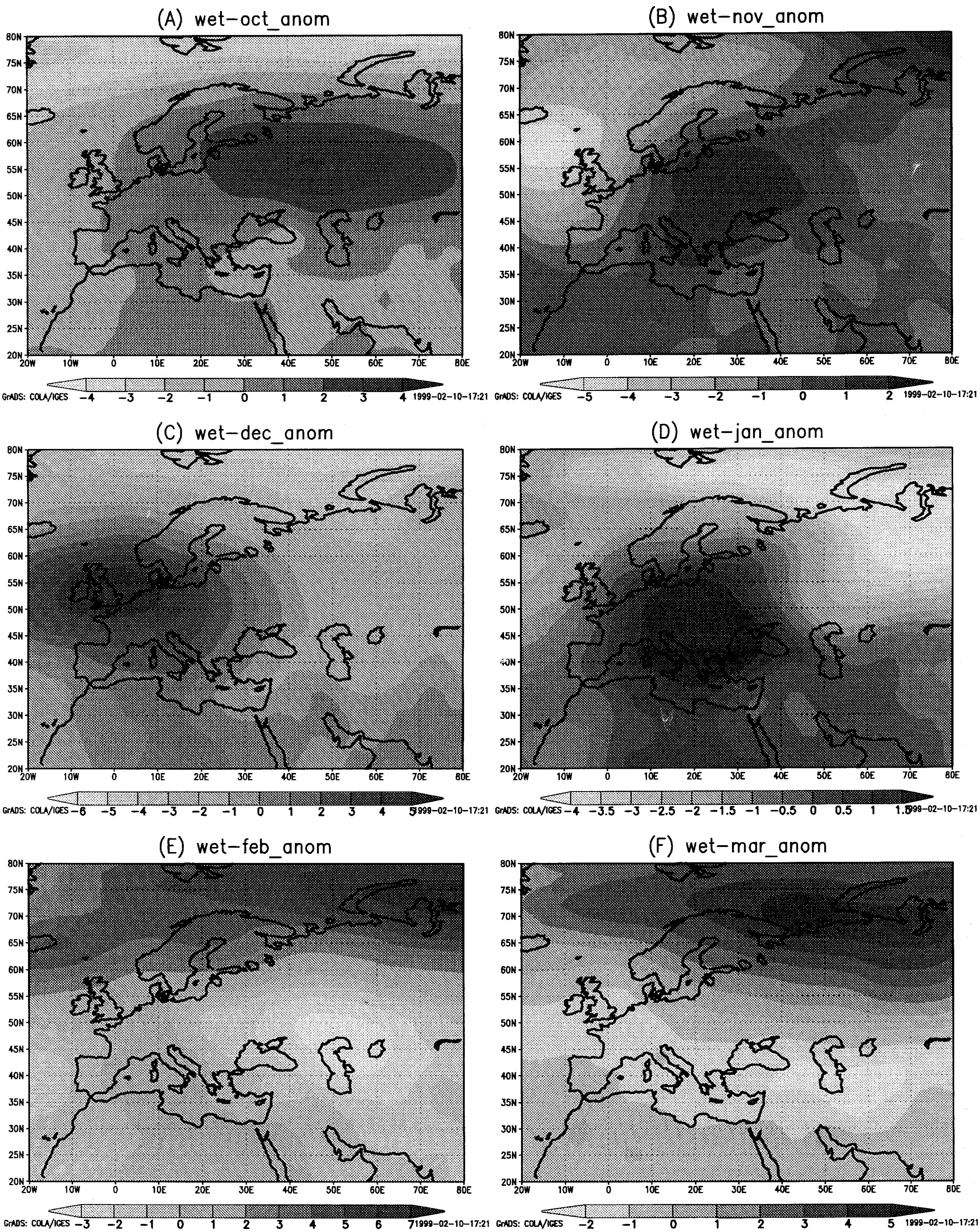

Fig. 2. Monthly mean sea level pressure anomaly (current minus normal) patterns (hPa) for wet months: (A) October, (B) November, (C) December, (D) January, (E) February, (F) March

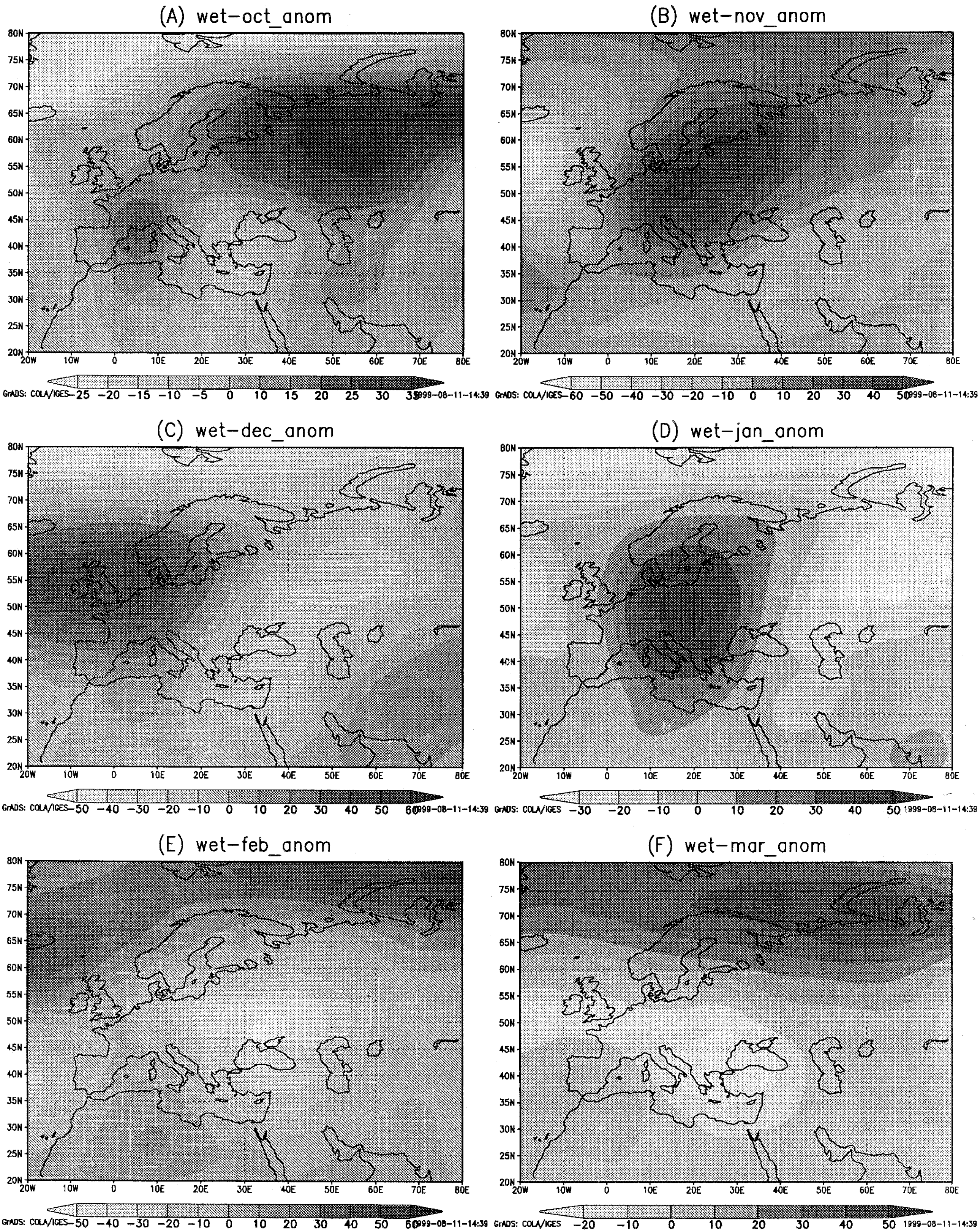

Fig. 3. Monthly mean H-500 anomaly (current minus normal) patterns (m) for wet months: (A) October, (B) November, (C) December, (D) January, (E) February, (F) March

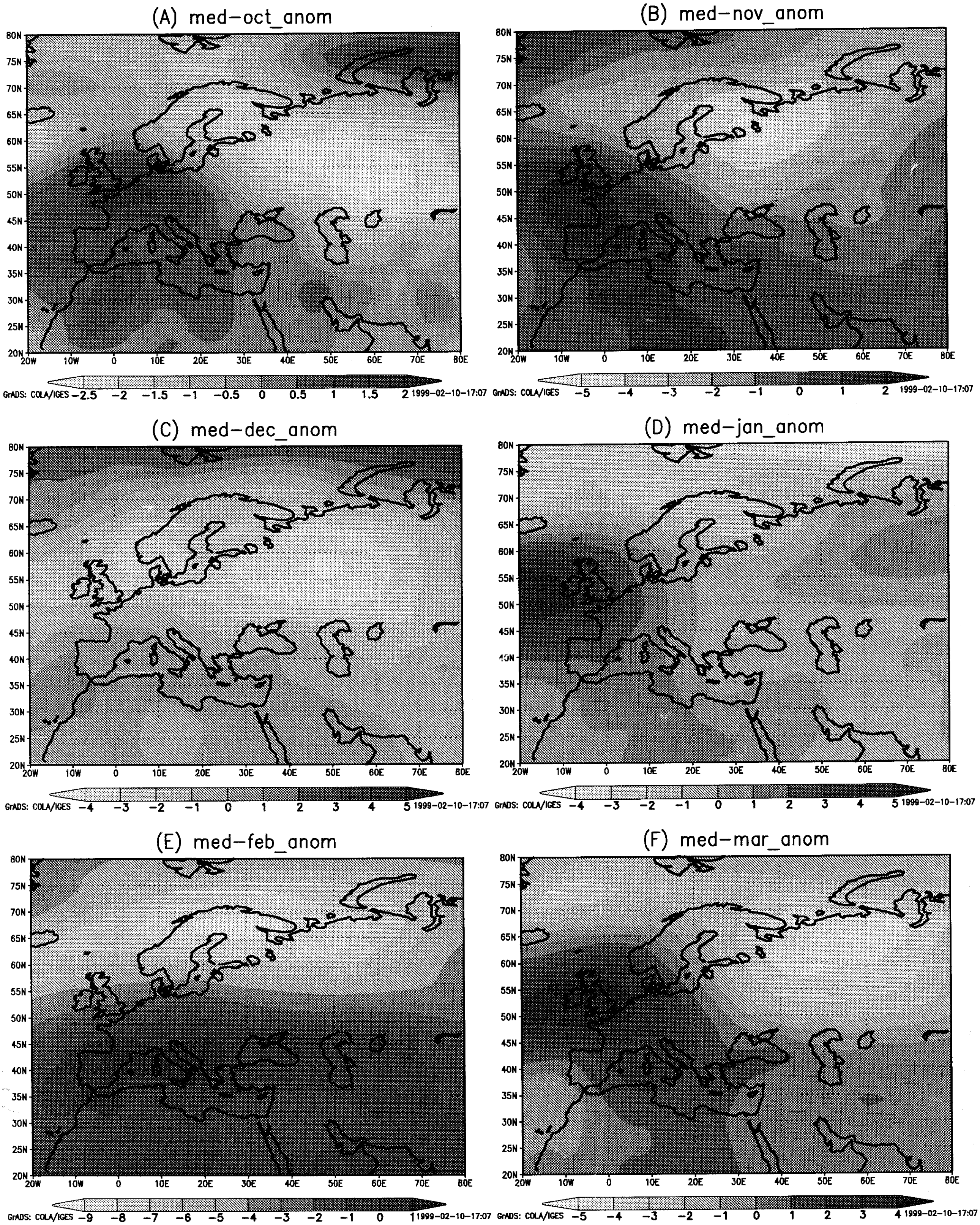

Fig. 4. As Fig. 2 but for medium months

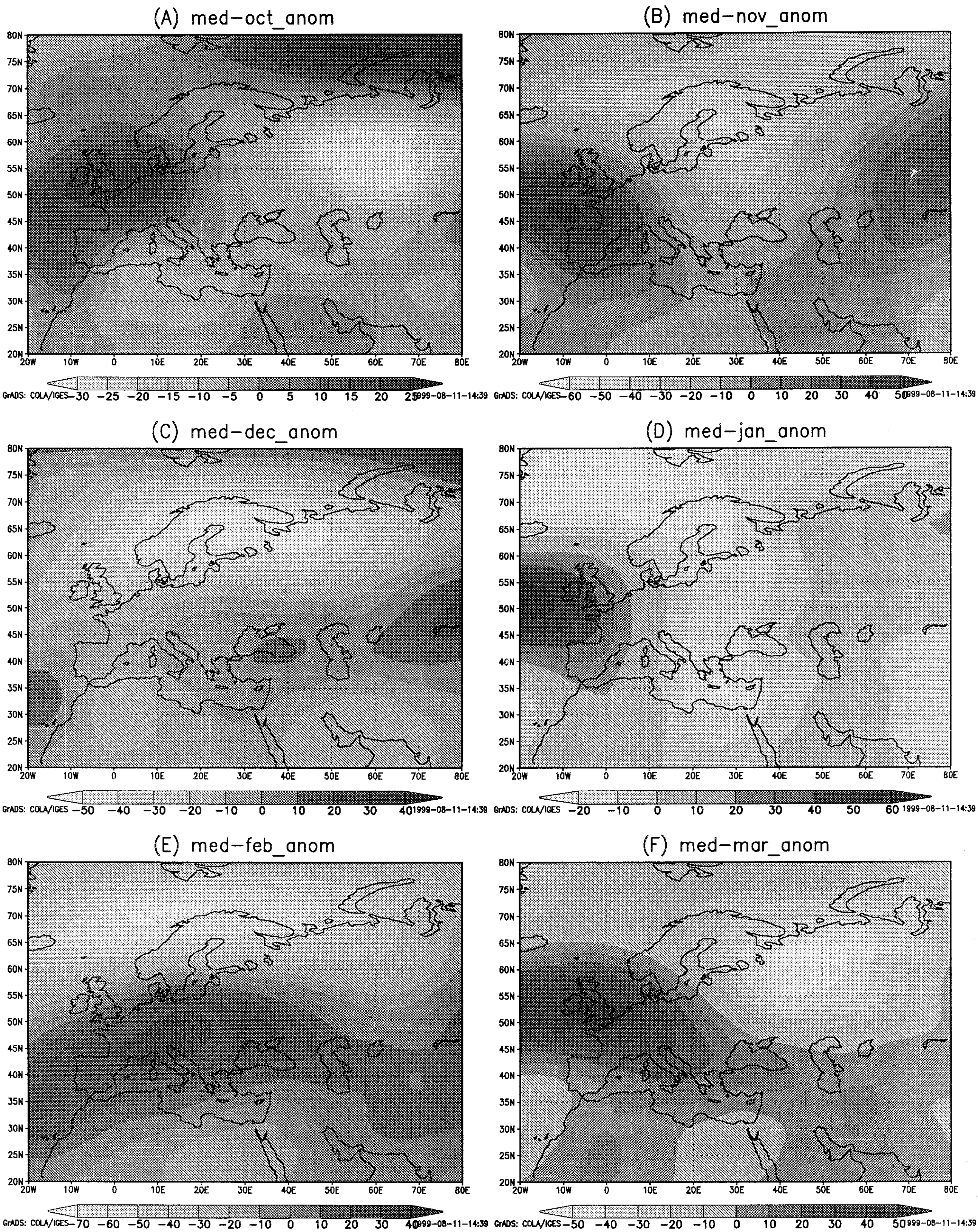

Fig. 5. As Fig. 3 but for medium months

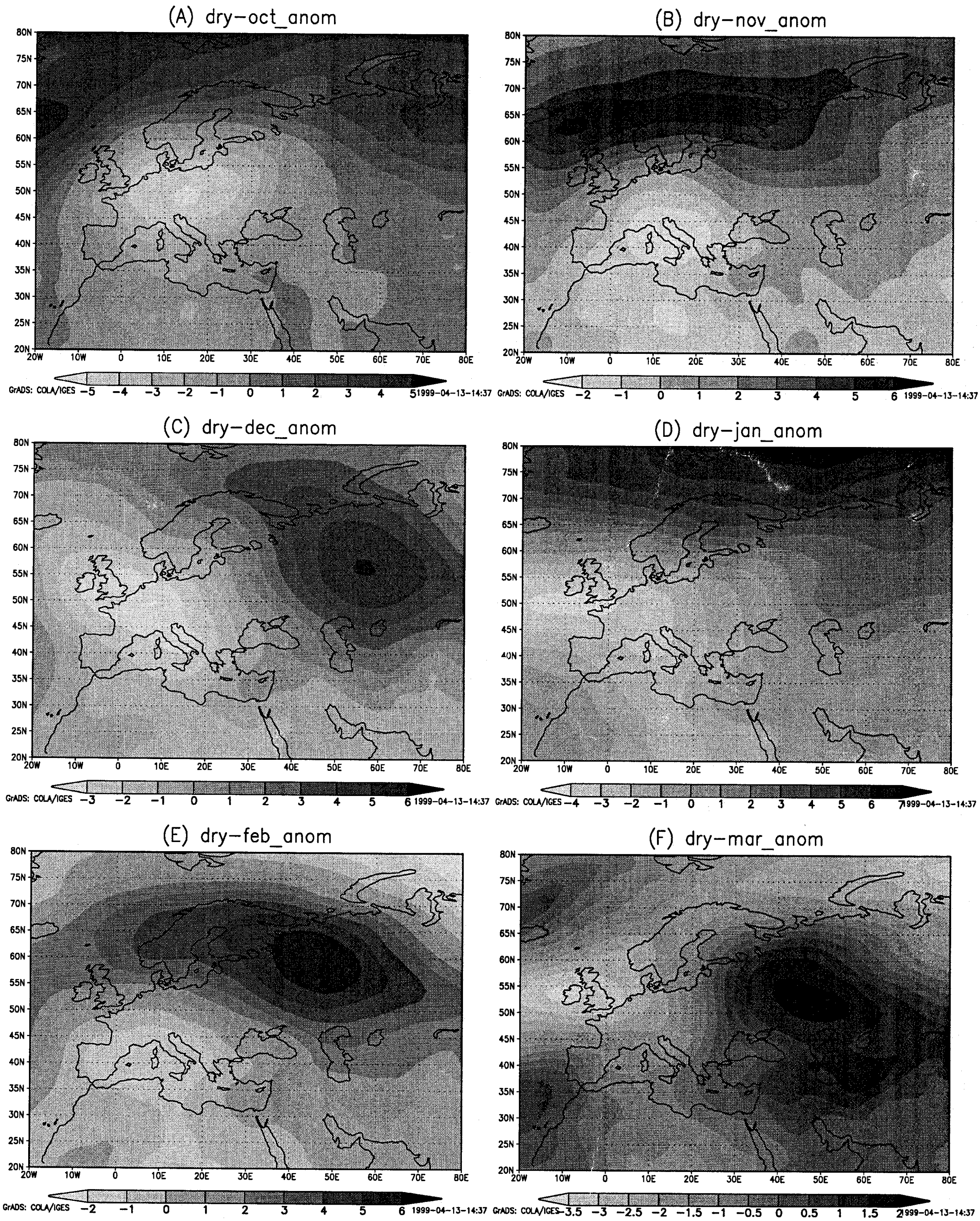

Fig. 6. As Fig. 2 but for dry months

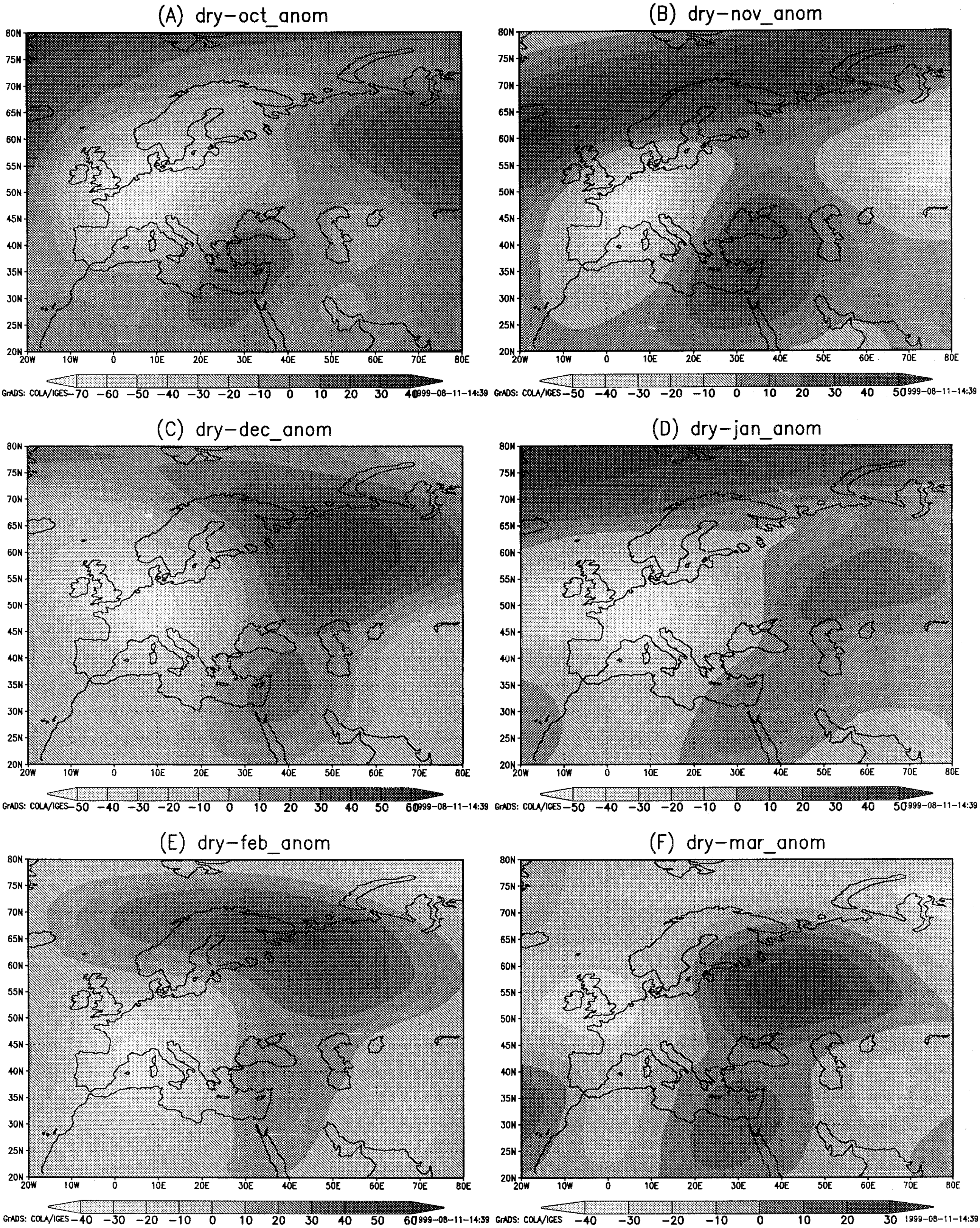

Fig. 7. As Fig. 3 but for dry months

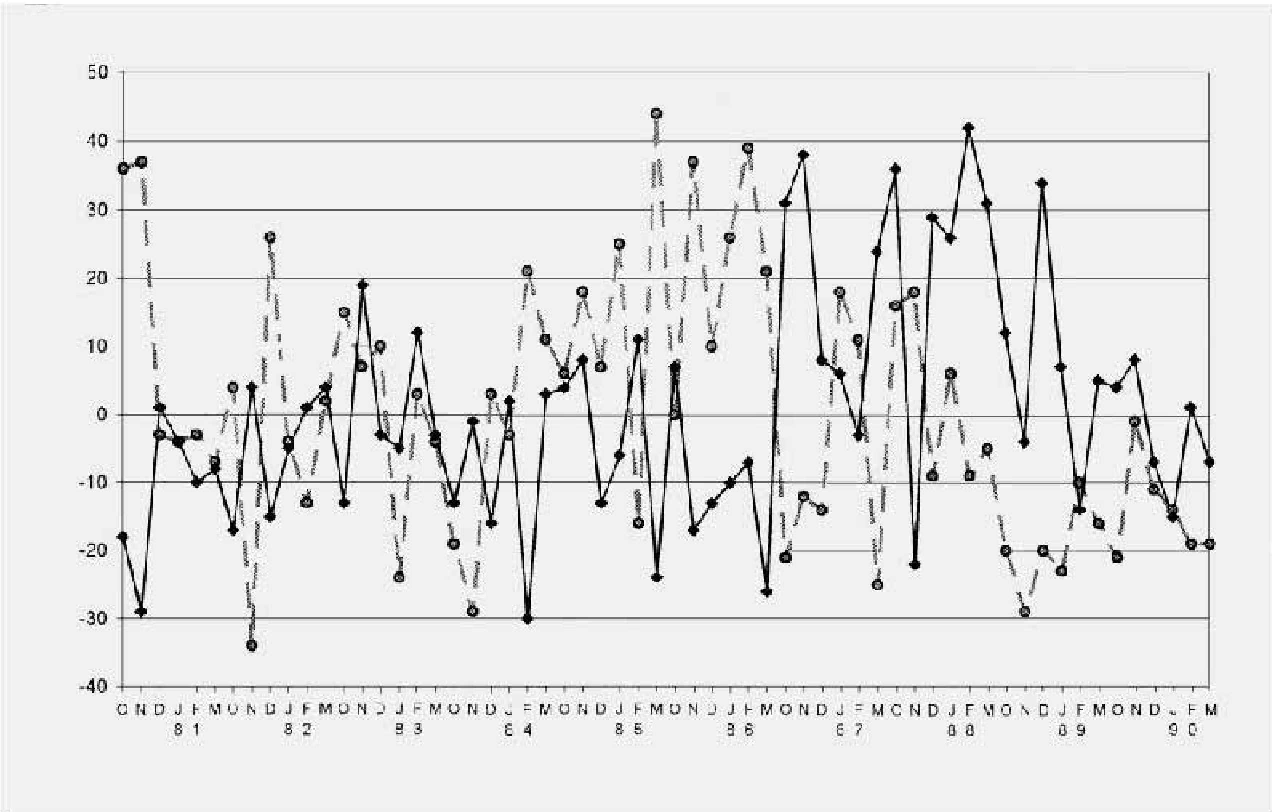

Fig. 8. Monthly mean precipitation anomalies (mm) during October–March period (1980–1990) over the Eastern Mediterranean (solid line) and Northern Mediterranean (dashed line) from the NASA reanalysis

intensive rainfall over one of the regions are often characterized by dry conditions over the other region.

The suggestion of the existence of inter-dependency between the EM and north Mediterranean precipitation is also supported by analysis of the mean SLP patterns. Averaged SLP patterns for the dry and wet 5-year periods are given in Figs. 9a–f and 10a–f, respectively. As could be expected, the main features of the SLP patterns are almost independent of the precipitation conditions in the EM. According to the patterns, the Mediterranean region and in particular the eastern-central area, serve as the saddle point between the Siberian and Azorean Highs. At the same time the central-eastern Mediterranean area appears to be the location of a trough system extending between the low over northern Europe and the Red Sea Trough (RST). The tropical – extra-tropical interaction appears to be important here – the trough over the Red Sea area is present in the monthly-mean SLP patterns of the both wet and dry sets.

Even so there are some quite significant differences between the wet and the dry 5-year mean SLP patterns. During the dry period (Fig. 9a–f) the Eastern European – Siberian anticyclone is more developed than its Atlantic – West European counterpart, while in the wet winter period patterns (Fig. 10a–f) the Atlantic – West European anticyclone prevails over the Siberian one. The intermediate "trough" zone or saddle area between these two intensive highs is normally located in the Mediterranean area. During the dry periods the main characteristics of the average SLP patterns are almost identical to those of the wet ones, however, the Siberian anticyclone is more intensive and the trough area is displaced to the west of the EM. During these periods the trough is located over the central and northern Mediterranean. During the wet periods the situation is different and the average SLP trough is positioned over the EM. This process appears to explain the negative correlation dependency between precipitation over the EM and North Mediterranean regions.

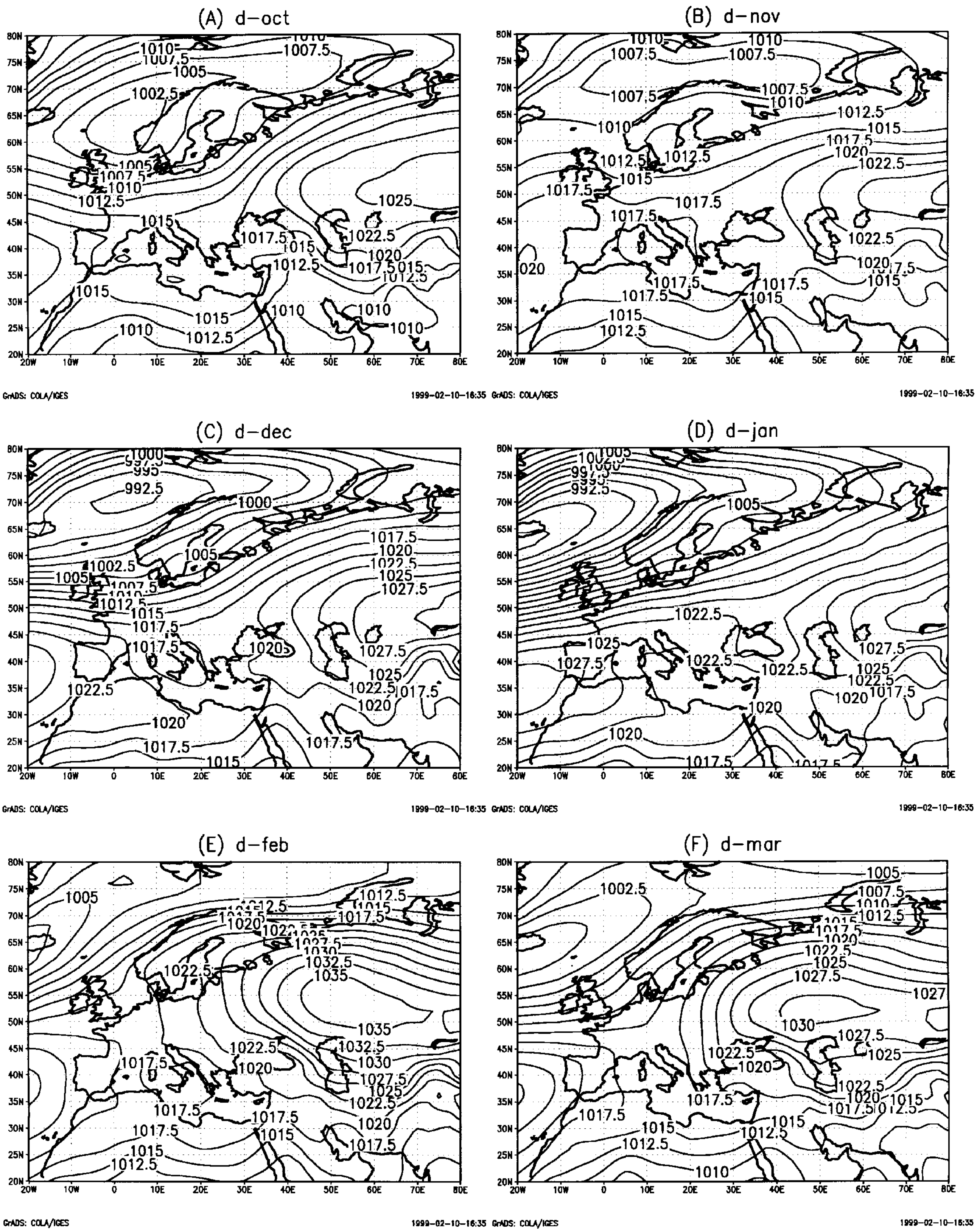

Fig. 9. Monthly mean sea level pressure (hPa) for the dry months in the Eastern Mediterranean region: (A) October, (B) November, (C) December, (D) January, (E) February, (F) March

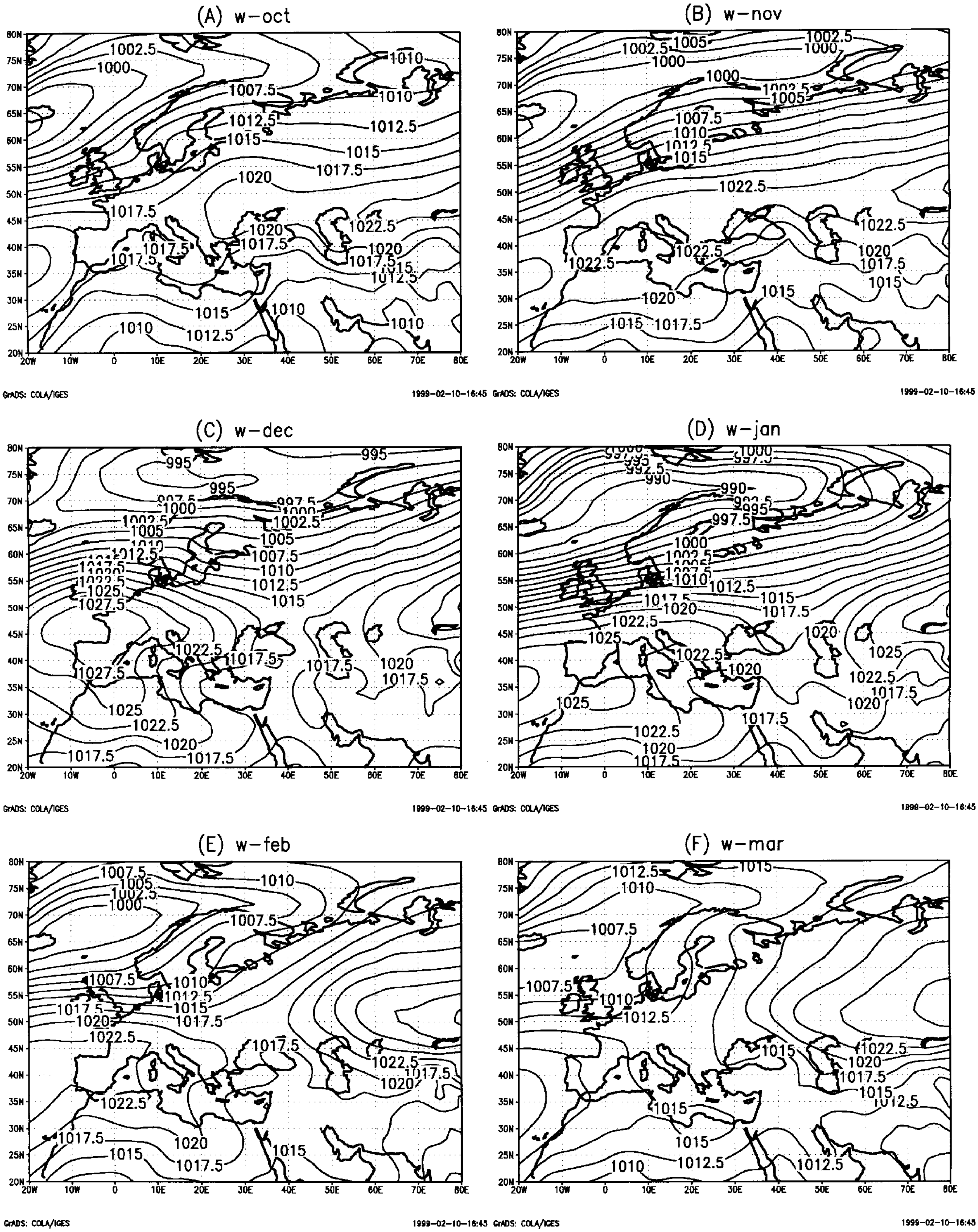

Fig. 10. As Fig. 12 but for the wet months

4. Summary and Discussion

Typical monthly-mean precipitation conditions over the EM region appear to be associated with some quasi-stable synoptic scale SLP and H-500 patterns over Europe and Asia. During the dry spells positive SLP and H-500 anomaly patterns prevail over Eastern Europe while negative SLP and H-500 anomalies are found over southwestern and Western Europe. A more intensive anticyclonic system over central Europe during dry EM seasons suggests an intensification of the westward advection of dry Asian air masses into the EM area. In contrast, during wet EM years there are mainly negative SLP and H-500 anomaly areas over Eastern Europe to northeast of the EM. At the same time, the anticyclonic system over the southern Atlantic and south-western Europe plays a more significant role by supporting the intensification of the midlatitude (western Europe) – tropical area (Red Sea) interaction processes in the EM area.

According to the data, a major part of EM precipitation is controlled by a large scale process associated with two main anticyclonic centers that influence the EM area, i.e. the Azorian and Siberian Highs. The results fully support the earlier conclusions by Kutiel and Paz (1998) concerning the typical SLP anomalies in the Mediterranean region during wet and dry rainy seasons. At the same time the new data allow a better understanding of the physical mechanisms responsible for the existence of such periods.

Recently Price et al. (1998) discussed the role of the ENSO conditions in the Mediterranean region. This suggestion supports the earlier results by Bengtsson et al. (1996) on the role of the STJ displacements in the EM region. According to the results, the STJ is more intensive and shifted closer to the equator during El Niño years in both hemispheres. This effect can play a role determining the precipitation intensity over the EM region (Krishnamurti, 1960; Krishnamurti et al., 1973; Krichak et al., 1997b). Another mechanism controlling the EM climate possibly played an important role during the Pinatubo eruption (Rosenfeld et al., 1991; Rosenfeld, 1992). Further investigation of this problem is necessary.

An additional remark on the dependency of precipitation in a relatively small area (such as Israel) on the area averaged precipitation over a larger region is necessary. According to our results, the EM area gets drier during periods with intensive anticyclones over central Europe. On the other hand, systematic anticyclonic conditions over Western Europe and the eastern Atlantic are more appropriate for wet conditions in the EM. According to recent studies (Alpert et al., 1991; Bengtsson et al., 1996; Druyan and Rind, 1991; Jeftic, 1991; Kay, 1991; Rind, 1998) such modifications may take place during the first half of the 21st century. The expected climatic changes in these regions may have serious consequences for precipitation regimes in the EM. According to Druyan and Rind (1991), global warming of the atmosphere may lead to a decrease in the intensity of the Siberian High by the year 2050. This would lead to an increase in cool season precipitation over the EM which therefore may be expected during the first half of the next century.

Acknowledgments

NASA reanalysis data for the period 1980–1995 were used in the study. The data on precipitation in Israel are obtained from the Israel Meteorological Service. The work has been performed with financial support from the Tel Aviv University Research Foundation Grant for 1998–1999.

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