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SEMI-OBJECTIVE CLASSIFICATION FOR DAILY SYNOPTIC SYSTEMS: APPLICATION TO THE EASTERN MEDITERRANEAN CLIMATE CHANGE

P. ALPERT,[a,*] I. OSETINSKY,[a] B. ZIV[b] and H. SHAFIR[a]
[a] *Department of Geophysics and Planetary Sciences, Tel Aviv University, Tel Aviv, Israel*
[b] *Department of Natural Sciences, Open University of Israel, Tel Aviv, Israel*

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ABSTRACT

Semi-objective classification of daily 1200 UTC synoptic systems was carried out by a discriminant-like analysis of the National Center for Environmental Prediction–National Center for Atmospheric Research reanalysis data over the eastern Mediterranean (EM) for 1948–2000. An example for a climate change application is given by the analysis of trends in the annual frequencies of the synoptic systems. The frequencies of the mostly dry Red Sea trough (RST) systems nearly doubled since the 1960s from 50 to about 100 days per year. This explains a dominant decreasing trend of rainfall in most of the EM, along with an increase in the southern part of the EM region, when the RST is deep enough to bring tropical moisture over this area. Also, the increasing tendency towards heavier daily rainfall in spite of the general decrease in the totals may be explained by the increase in the active and stormy types of RST situations. The annual frequency of the Cyprus lows was noticed to drop slightly in 1983–98 to 26, compared with about 30 during 1967–82. The high positive correlation between the recent increase in the North Atlantic oscillation index and the pressure over most of the EM countries is linked to these tendencies in the synoptic systems. Copyright © 2004 Royal Meteorological Society.

KEY WORDS: climate change; eastern Mediterranean climatology; synoptic systems classification; discriminant analysis; surface meteorological fields

1. INTRODUCTION

The objective classification of synoptic systems has been a topic of much interest in climatology, for the purposes of identifying potential air-pollution situations, long-range forecasting, and the study of rainfall and other weather phenomena, since the pioneering work by Lamb (1950, 1972). Lamb proposed a catalogue of daily weather types over the British Isles as related to categories of synoptic circulations. Recently, there has been increased interest in the study of climate variations, and in particular those potentially related to global changes and greenhouse-gases warming, e.g. Intergovernmental Panel on Climate Change (IPCC, 1990–2001). Over the Mediterranean, it has been shown that there is an overall trend of decreasing rainfall with an increase in the frequency of heavy rainfall (Alpert *et al.*, 2002). Contrary to many mid- to upper-latitude regions of the world in which positive trends in recent rainfall were reported, several regional studies over the Mediterranean show a dominant decreasing trend. In particular, over the central-western Mediterranean basin, Italy and Spain, the precipitation trends for 1951–95 indicate an average reduction of about 10–20%, which is statistically significant (Piervitali *et al.*, 1998; Romero *et al.*, 1998). The greatest decrease of 26% (157 mm) occurred over the southern belt, including southern Italy, southern Spain and Tunisia. In the eastern Mediterranean (EM), however, mixed rainfall trends are found, but clearly more stations show decreasing trends. These include Jordanian stations for the period 1938–68 and most stations over Greece, Turkey, Syria, Lebanon and Israel for the period 1951–90; all of them showed decreasing trends (Paz *et al.*, 1998; Kadioglu *et al.*,

* Correspondence to: P. Alpert, Department of Geophysics and Planetary Sciences, Tel Aviv University, Tel Aviv, Israel;
e-mail: pinhas@cyclone.tau.ac.il

1999). An exception to this decreasing trend is a relatively small area over the southeastern EM (northern Negev semi-arid zone in central-southern Israel), where an increasing trend in the total amounts of rainfall was shown and suggested to be partly associated with the recent substantial modifications in land cover and land use (Alpert and Mandel, 1986; Otterman *et al*., 1990; Ben-Gai *et al*., 1993, 1994, 1998; Steinberger and Gazit-Yaari 1996). The potential impact of land-use change over Southern Israel on the increase in rainfall and convection, particularly in October, was illustrated through high-resolution meso-scale simulations by Perlin and Alpert (2001).

However, a question remains about the potential contribution of the large-scale synoptic changes to this positive rainfall tendency. In addition, it is of much interest to identify the potential changes in the distribution of the typical synoptic systems over this sensitive semi-arid region. For instance, is the frequency of the Cyprus lows, which contribute most of the rainfall over the EM (Shay-El and Alpert, 1991; Segal *et al*., 1994), decreasing? Does the frequency of the Red Sea trough (RST) increase? The RST is a surface trough extending from East Africa through the Red Sea toward the EM and is normally associated with dry and warm weather, except infrequent cases where severe storms develop — the active RST; see later.

Earlier objective classifications over this area were reported by Koplowitz (1973), Ronberg (1984), Ronberg and Sharon (1985) and Shafir *et al*. (1994); however, those studies were all done for shorter periods (1 year, or in selected seasons), and/or fewer grid points (Figure 1 (Shafir *et al*., 1994)) and employed other techniques (principal component analysis (PCA), cluster-analysis). Also, Koplowitz's and Ronberg's classifications were based on radiosonde, surface and weather data.

Kalkstein *et al*. (1996) applied discriminant function analysis for the air masses. Their number of cases (vectors) for each class of the training set was larger than the dimensionality of the vectors, i.e. seven. This allowed them to use discriminant analysis (DA) as well. We dealt with the synoptic systems defined by a 100-dimensional vector and, since we had less than 100 members in the training set classes, this required the modification of the classical DA, as described in Section 2. Our grouping is somewhat similar to the self-organizing maps method (Kohonen, 2001).

Since the EM synoptic systems for 1948–2000 were automatically classified by the method proposed here, several applications have been noticed and partly realized. The first application of the classified daily synoptic

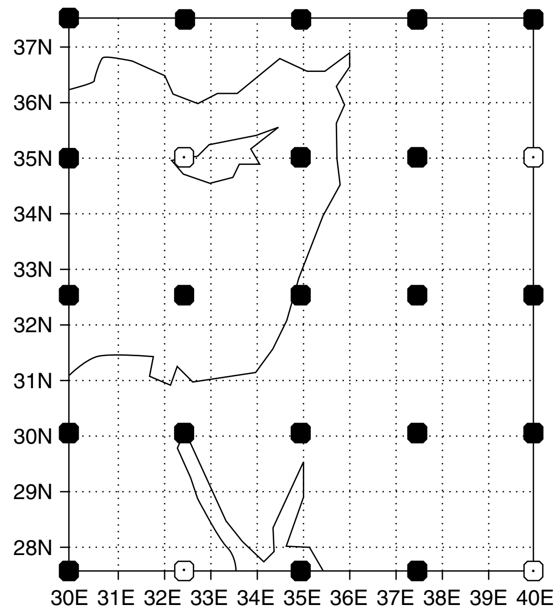


Figure 1. The 25 grid points employed for the objective synoptic systems classification over the EM, including Israel, northeastern Egypt, Cyprus, southern Turkey, Syria, Lebanon and Jordan. Latitudes and longitudes are indicated. The open circles denote four points employed in the earlier study by Shafir *et al.* (1994). The grid dataset is from the NCEP–NCAR reanalysis Website

systems to the climate trends analysis is given in Section 4, interpreting the annual frequencies of the daily synoptic systems. The second application is described in a companion paper (Alpert *et al*., 2004) that proposes a new definition of seasons, termed synoptic definition, that fits the regional climate well. The description of a third application to the evaluation of a general circulation model is given by Osetinsky and Alpert (2004).

2. REVIEW OF PREVIOUS CLASSIFICATIONS

2.1. General

Lamb (1950, 1972) carried out pioneering synoptic systems studies. He defined the synoptic systems according to the different airflows for the British Isles during 1898–1947. Also, Flöhn and Hess classified the large-scale patterns of airflow in the lower troposphere (Grosswetterlage) for central Europe (Barry and Chorley, 1970).

The contemporary methods have been broadly reviewed by Yarnal *et al*. (2001): 'Traditional synoptic climatological techniques have at times been used as forecasting tools, but because they use a small set of generalized discrete weather-types, they are generally bettered by other empirical and numerical predictive approaches'.

Maheras *et al*. (2000) describe a method of classification of circulation types in Greece based on prescribed manual definitions and automatic recognition of location of circulation patterns' centres with respect to Greece. They defined 20 circulation types. Their classification is based on the National Centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research (NCAR) reanalysis data for 00Z, 06Z, 12Z, and 18Z, and daily means for the eight grid points within the area of 20–60 °N and 20 °W–50 °E. The fields used are sea-level pressure (SLP) and geopotential heights at the 500 hPa level. The patterns described are much larger then the EM weather patterns. The authors use the results for variability and trend analysis. Their results are presented at yearly and seasonal scales. The frequencies of the daily patterns are computed as number of days per year, or seasonal means over 1958–97. In their trend analysis, the decreasing trend of the rainfall is connected to that of the cyclonic circulation types. Such a connection over Greece differs principally from the situation in our present analysis, where the RST (cyclonic circulation) days are primarily dry.

Ramos (2001) classified manually every year out of the 111 years (1889–1999) into one of five classes according to the combination of rainfall recorded during the two main periods: spring (March–June) and autumn (September–October). The climate analysis for the western Mediterranean is described in terms of years varying from very dry to very wet.

Huth (2000) presents a method that is a modification of PCA. Huth (2000) examines his method of classification of daily circulation patterns in application to analyses of circulation for Europe in general circulation model (GCM) outputs. That application aims both at validation and examination of the GCM climate change response, by comparing GCM-simulated and observed climates. The classification procedure is applied to the observed daily H500 patterns and those simulated by the control and $2 \times CO_2$ ECHAM3 GCM runs.

Most of the European classifications include at their first step some subjective definitions that guide the consequent objective classification.

The European classifications have their regional advantages because they were designed for regional applications. In Europe and middle latitudes, the synoptic-scale patterns largely control the climate. Therefore, the European classifications, i.e. by Lamb (1950, 1972) for the British Isles, by Maheras *et al*. (2000) for Greece, by Ramos (2001) for the western Mediterranean and by Huth (2000) for Europe deal with such patterns; and much attention is paid to dividing all synoptic systems into two main classes, i.e. cyclonic and anticyclonic (low-pressure patterns and high-pressure patterns), which are sharply different in their associated weather conditions.

The principles described above are not directly applicable to the EM region, where low-pressure systems like the Persian trough, RST and Sharav low are associated mainly with non-rainy and even sometimes very dry weather. These systems may rarely generate some precipitation over limited areas during short times.

The precipitation over the southern part of the EM region might be caused by the RST only when it is deep enough to bring tropical moisture or to generate a small rainy low over the southeastern corner of the Mediterranean Sea. Even in such cases, there are only small amounts of precipitable water that often evaporate in the hot air before reaching the surface. Also, we cannot use the large-scale European patterns classification for EM weather, because the latter is governed by much smaller synoptic systems, originating from both mid-latitudinal and tropical areas and modified over the complex EM terrain, which includes sea, deserts, mountains, valleys, and steppes, e.g. see Alpert and Neeman (1992). Note, classifications for other regions are not examined here. Among them there is the synoptic classification for Australia performed by Dahni (2003). The common method of reducing the dimensionality of data by PCA was used in that study. It seems to us that even the high variance percentage explained does not justify the loss of information, especially over the complex terrain characterizing the EM.

2.2. *Past EM classifications*

Synoptic classifications have been carried out for the EM region as well. Israel is often referred to in many EM climate examples because its geographic position means that most of the climatological features of the eastern Mediterranean are also observed in Israel.

Koplowitz (1973) performed the first objective classification of EM synoptic pressure field patterns. Ronberg (1984) carried out a synoptic systems classification over the southeastern EM coastal plain (Israel) for the cool rainy period that he defined from October to April (7 month period). His classification was based on radiosonde and surface data. A set of 192 atmospheric variables at the surface and aloft was reduced by PCA to a set of 12 compound variables. Eighteen weather types were found by a cluster analysis for the coastal plain during the cool period. The 18 types were sub-divided subjectively into four groups: (i) RST types, (ii) transitional types, (iii) Sharav-like types, and (iv) stormy types. Since he dealt with the cold season only, summer systems like the Persian trough were not included. Shafir *et al*. (1994) carried out a cluster analysis classification of EM synoptic systems for 1985, based on gridded European Centre for Medium-range Weather Forecasting data. Some efforts were recently made to analyse the different monthly mean synoptic patterns over the EM for rainy and dry months (Kutiel, 1985). Marco, Seter and Sharon (personal communication) also recently performed an objective classification for some winter periods for the purpose of model verification.

These EM studies have linked important weather features like strong winds, heavy rainfalls and floods to the synoptic systems. Investigations were done, for example, for wind energy regimes by Alpert *et al*. (1987) and Shafir *et al*. (1994); for floods by Kahana *et al*. (2002); and for high tropospheric ozone days by Dayan and Levy (2002).

The earlier EM classifications cited above had one or more of the following limitations: much manual work, short sampling period, focusing primarily on winter or summer and a small number of variables. In this study we use, on the one hand, the reanalysis data from 1948 that include many meteorological variables and, on the other hand, powerful computers that allow one to perform many computations quickly on huge matrices. These factors allow one largely to overcome the aforementioned limitations. The EM classifications that are based on cluster analysis (Ronberg, 1984; Shafir *et al*., 1994) have excluded or significantly limited the subjective manual step. Our attempts to continue in this direction for classification of synoptic systems over the EM during a long-term period and through the entire year have yielded no satisfactory results. The reason is that cluster analysis focuses on the quantitative similarity and difference of the objects in a purely mathematical manner, whereas in meteorology the experts may easily recognize significant and non-significant subtle qualitative differences among the synoptic systems. Local weather phenomena, e.g. like precipitation amounts and duration, are very sensitive to minor differences in the route or location of the synoptic systems in conjunction with the complex EM topography. Consequently, we propose a method based on experts' experience. The results of verification of our method encourage us to continue the classification work in this direction.

3. CLASSIFICATION METHOD AND DATA

3.1. The DA method and its modification

Classical DA consists of three stages (Hand, 1981; Wilks, 1995; Von Storch and Zwiers, 1999). The first stage is manual. Experts divide a limited but representative set of objects (samples) into several groups (classes). These predefined classes of samples serve as a training set for the DA program that will automatically classify the entire dataset and also create the multi-variable space. The dimensionality of this space is the number of variables describing each object. In the second stage, the DA program defines the discriminant (dividing) surfaces between each pair of the classes. These surfaces are described by the discriminant functions in a DA computer program. Finally, the DA program classifies each of the raw objects into any of the predefined classes according to its best fit to that class. Calculation of the discriminant functions is subject to the objects' dimensionality, which must be less than the number of samples in the smallest class. This constraint is quite a problem in synoptic systems classification, since synoptic systems are normally described by several meteorological fields at many grid points. For example, in our work, at least 100 variables are required for each daily map for the EM region. The number 100 is obtained as follows. The EM region is defined by the square 27.5 °N, 30 °E to 37.5 °N, 40 °E, including 25 grid points with an interval of 2.5° from the NCEP–NCAR reanalysis data site at http://www.cdc.noaa.gov/ (Figure 1). The synoptic systems are described by four fields: geopotential height H, temperature T and two horizontal wind components U and V at 1000 hPa. Hence, four fields (H, T, U, V) at 25 points yield 100 variables for one pressure surface only. As stated above, for a 100-dimensional space the smallest class should include at least 101 samples.

In the present work we modified the classical DA method. The reason is that the number of samples in the smallest class of our training set (see below) is smaller then our dimensionality (100). It is worthwhile mentioning that, in principle, one could think of reducing the dimensionality of the space considered. This, however, would require further study in order to validate the different reduction methods.

3.2. Methodology: EM synoptic systems

Our work has been carried out as follows. Prior to subjective classification, five experts defined 19 classes of EM synoptic systems. These 19 classes belong to six large synoptic groups, as given by the common names being widely used in most of the EM countries:

- The Cyprus lows, which are the main part of the 'winter lows' group. They contribute winter rainfall of high intensity that lasts for about 2–3 days on a typical occasion in Turkey, Cyprus, Syria, Lebanon, Israel, and sometimes also northeastern Egypt (e.g. Shay-El and Alpert, 1991).
- The Persian trough ('summer trough') is a persistent summer weather condition in these same countries, plus Jordan and Iraq (Alpert *et al.*, 1990a).
- The RST (or 'Sudan trough') is situated over the Red Sea and its surrounding countries throughout the year; during the cold season, the RST deepens northward, sometimes reaching the Turkish coastline (e.g. Dayan *et al.*, 2001).
- The Sharav lows ('sharav' means hot weather; also called North African depression; another local name is 'khamsin low'; 'khamsin' means heat wave, sirocco; 'khamsin' is 'fifty' in Arabic, referring, as some suggest, to the nearly 50 days' duration of the hot and dusty winds in spring that have been observed for centuries). These are the typical spring phenomena for the southern EM countries like northern Egypt and Israel (Alpert and Ziv, 1989).
- The 'Siberian high' and 'Subtropical high' are widely used names for the last two groups.

Subdivision within each of the common EM synoptic groups is carried out according to the location/depth and the field gradients of the specific systems over the EM region (Figure 1). A detailed list of the EM synoptic systems is given next:

- The different winter-low situations are named according to (i) the location of their centres along their path over the Mediterranean Sea as related to the island of Cyprus and (ii) their depths and gradients. Cold lows are to the west; Cyprus lows are deep/shallow to the north/south; deep/shallow lows are to the east. Thus this adds up to seven classes for the winter-low situations.

- The RST consists of three classes: with eastern/central/western axes. The locations of the axes are defined relative to the EM eastern coastline, i.e. the Levant.
- The Persian troughs are divided into three classes: deep/medium/shallow.
- The Sharav lows group was especially subdivided as related to Israel, i.e. for the Sharav special weather phenomena (hot and dusty air masses of desert origin) that are experienced mainly over most of Israel and particularly Egypt. For this reason, the Sharav lows group consists of two types: to the west of and over Israel, depending on the instantaneous location of this fast-moving low at the sampling time.
- Siberian highs (winter highs) are divided into three classes: to the north, east and over Israel. The summer subtropical high is defined as high to the west of Israel, according to the governing direction of the pressure gradient. It is convenient to relate these names to Israel due to its location at the southeast corner of the Mediterranean and in the centre of the region studied.

The total number of synoptic systems is therefore 19. For further details on the above 19 types, see Alpert *et al.* (1990a,b) and Alpert and Neeman (1992).

3.3. Methodology: subjective classification

The experts have subjectively classified the synoptic system for each day of one representative year, 1985, based on sea-level pressure daily maps at 1200 UTC from the NCEP–NCAR reanalysis (http://www.cdc.noaa.gov/). The experts inspected the spatial SLP distribution, considering also the date of the year (expressed as cold, warm or transitional season). The latter was found useful in ambiguous cases. The year 1985 was selected because it had been already subjectively analysed for summer and winter by Alpert *et al.* (1987) and objectively analysed by Shafir *et al.* (1994). For 1985, 335 daily maps were distributed distinctly into 19 types, whereas 30 daily maps could not be clearly classified and were, therefore, excluded from the expert-defined database. Also, since the year 1985 was relatively poor with rainy Cyprus lows situations, the predefined database was enriched by the winter (December–February) of 1991–92. Hence, the entire expert-defined database consisted of 335 days (1985) + 91 days (1991–92), i.e. total of 426 days.

The numbers of days eventually found in the classes of the expert-defined database that served as a training set were as follows.

deep/shallow Cyprus lows to the north: 19/18 respectively; deep/shallow Cyprus lows to the south: 3/1 respectively; cold lows (to the west of Cyprus): 19; deep/shallow lows to the east: 21/26 respectively; RSTs with the central/western/eastern axis: 34/4/50 respectively; deep/medium/weak Persian troughs: 6/42/49 respectively; Sharav lows to the west/over Israel: 6/5 respectively; and highs to the east/west/north/over Israel: 11/59/34/19 respectively. All the numbers sum up to 426.

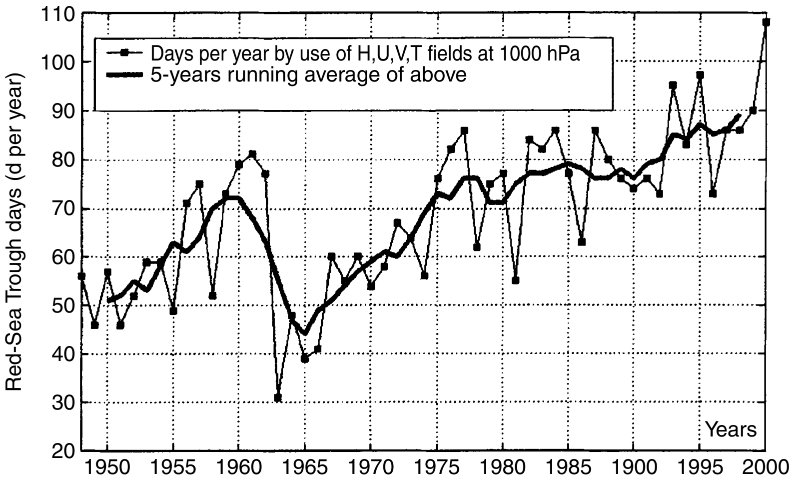
3.4. Methodology: database representation and verification

The matrix of the entire dataset was built as follows. Each row, representing an individual day, contained 100 variables for any specific day from 1 January 1948 to 31 December 2000, and each column corresponded to one of these variables at a certain point. This matrix was normalized in a standard way. Namely, for every individual column each variable x was replaced by $(x - \mu(x))/\sigma(x)$, where μ denotes the mean value and σ the standard deviation. The predefined above-mentioned 426 days are obviously a subset of this matrix. Now, for each row of the matrix, representing a specific day in 1948–2000, 426 Euclidean distances from the expert-predefined rows were calculated. The predefined day, to which the minimum distance was found, determined the class to which the specific day should be assigned. In this way we have circumvented the problem of small numbers of objects in our classes compared with the large number of variables making it impossible to build the discriminant functions, as is the case in classical DA.

We verified our approach by checking 50 objectively classified days randomly selected from the whole period 1948–2000 against their evaluation by the same experts. In only one case out of the 50 daily maps was the automatic classification found to be unsatisfactory. It turns out that, for this day, the SLP map presented a col case with weak gradients and, therefore, was at the margin of several predefined synoptic systems.

4. ANNUAL FREQUENCIES OF THE SYNOPTIC SYSTEMS AND THEIR INTERPRETATION

Figure 2(a) and (b) shows the inter-annual variations in frequencies of occurrence of RST and Cyprus low days respectively, during 1948–2000. Typical SLP maps for these two synoptic systems are shown in Figure 3(a) and (b). The RST system (Figure 3(a)) is typified by a dry easterly flow, which is normally associated with dry weather conditions, although occasionally it can lead to intense flooding when moisture sources from the south reach our region (e.g. Ashbel, 1938; Itzikson, 1995; Krichak *et al.*, 1997a,b; Dayan *et al.*, 2001). The active RST was documented by Kahana *et al.* (2002) and defined as: 'a surface trough extending from East Africa through the Red Sea toward the Eastern Mediterranean, accompanied by a pronounced trough at 500-mb level over eastern Egypt'. The drought period, which was experienced during 1956–62, is being



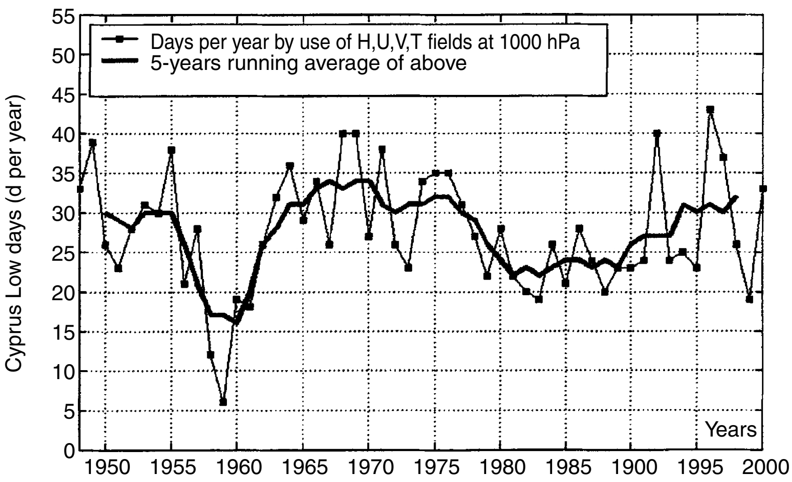


Figure 2. Annual numbers of days (frequencies) for 1948–2000: (a) RST; (b) Cyprus low. Thin lines with squares indicate results obtained by use of H, T, U, V fields at 1000 hPa level. Heavy lines are the 5 year running averages

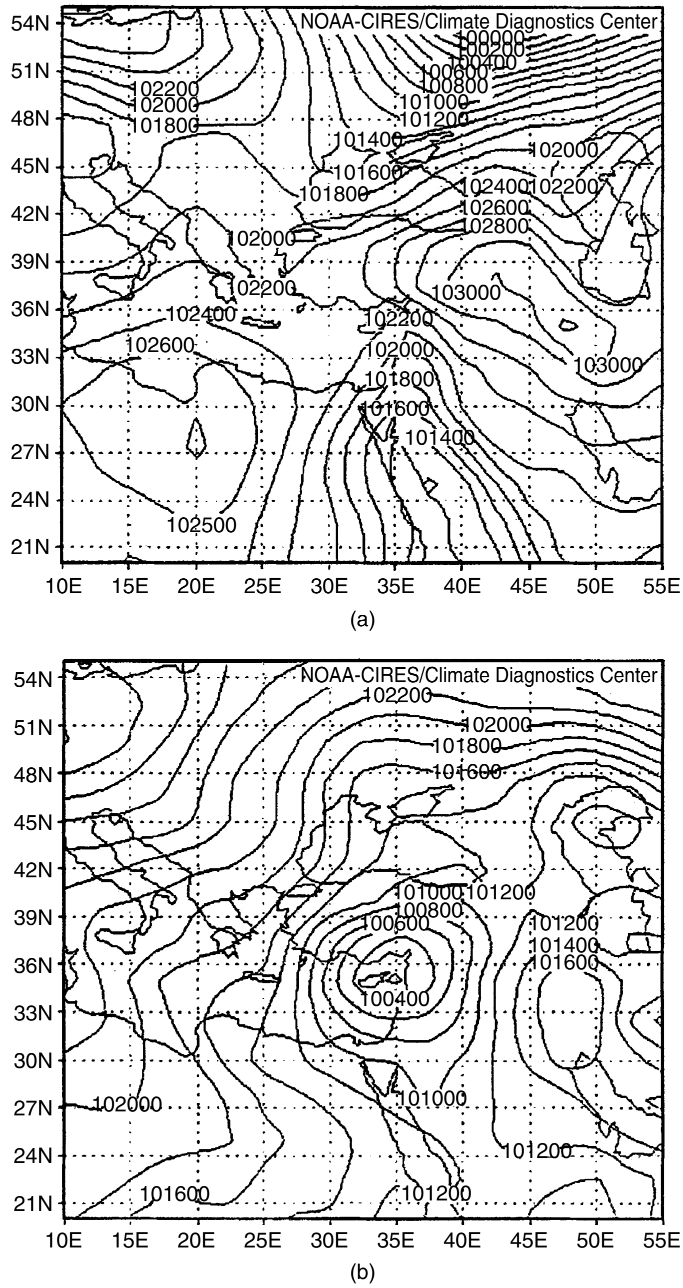


Figure 3. Examples of typical EM synoptic systems by SLP maps: (a) RST on 10 January 1992 at 1200 UTC; (b) Cyprus low on 31 January 1992 at 1200 UTC. The isobaric interval is 200 Pa (2 mbar). The EM maps are from the NCEP–NCAR reanalysis Website

typified in Figure 2(a) by an increase of the annual number of RST days to about 71–80 (and a drop in Cyprus lows, next). Since 1965, having about 40 RST days, there is a distinct increasing trend in the RST frequency, reaching unprecedented values of about 85–108 days in the 1990s. The distribution of the RST frequencies as well as any other EM synoptic system during any period was found to be far from Gaussian (i.e. highly skewed or of more than one mode); therefore, a standard significance test was not carried out, since it was not valid. The RST frequency increase fits well the dramatic increase in RST-related floods reported by Kahana *et al.* (2002) and the general Mediterranean trend in rainfall (Alpert *et al.*, 2002).

Table I. Summary of frequencies of the EM synoptic systems for the years 1970, 1985 and 2000. The classification given here was based on the H, T, U, V fields at the 1000 hPa level. The three types of RST were merged into one group. Same for Persian troughs (three types), highs (four types), etc

Synoptic system	1970		1985		2000	
	No. of days	% of total	No. of days	% of total	No. of days	% of total
Cyprus lows	**27**	7.4	**21**	5.7	**33**	9.0
Cold lows to the west	**12**	3.3	**8**	2.2	**6**	1.7
Sharav lows	**4**	1.1	**9**	2.5	**3**	0.8
Lows to the east	**23**	6.3	**25**	6.8	**28**	7.6
RSTs	**54**	14.8	**77**	21.1	**108**	29.5
Persian troughs	**109**	29.9	**109**	29.9	**111**	30.3
Highs	**136**	37.2	**116**	31.8	**77**	21.7
Total	**365**	100	**365**	100	**366**	100

In contrast to the RST synoptic system, the Cyprus low (Figure 3(b)) is the major contributor to most of the rainfall over the EM (Alpert *et al*., 1990b; Shay-El and Alpert, 1991) with an average frequency of about 28. In dry years, the number of Cyprus lows drops, as noticed, for instance, during 1956–62, when their average frequency was only about 19. The average frequency of Cyprus-low days seems to drop slightly in 1983–98 to about 27, compared with about 30 during 1967–82. These changes may be associated with the recent increase in the North Atlantic oscillation, which is correlated with pressure and negatively correlated with temperature over Israel during winter (Ben-Gai *et al*., 2001). Higher SLP and lower temperatures in the EM during winter are associated with increased Siberian highs to the north and RSTs to the south because, as pointed by Saaroni *et al*. (1996): 'The Levant region is located between the barometric ridge from the north (EM) and the RST from the south. The pressure gradient developed between the ridge and the trough causes easterly winds, often quite strong, in the Levant region'.

Table I illustrates the changes in the frequency of the main synoptic systems in the last 30 years as reflected in the years 1970, 1985 and 2000. In this way, we circumvent the increase of the RST frequencies during the drought in the late 1950s–early 1960s. Table I shows that the frequencies of RST days were doubled from 54 to 108 during 1970–2000. The increased RST frequency corresponds to the general decreasing trend in total rainfall over the EM described earlier, since most RST situations are associated with dry winds from the easterly dry sector (Saaroni *et al*., 1998). As mentioned above, the RST frequency increase may also correspond to the increase in heavy rainfall days on account of weaker rainfall days (Alpert *et al*., 2002; Kahana *et al*., 2002). This is especially true in southern Israel, due to the active RST situations associated with flooding over that area. Also of interest is our finding that the increase of RST frequency is partly on account of the reduction in the frequency of highs.

5. SUMMARY

A set of the regional synoptic systems is suggested as a powerful tool for regional climatology trends analysis. Such a set might be obtained as a result of objective or semi-objective classification. The proposed semi-objective method of classification of the huge long-term dataset into 19 definite classes is easy to use. The method is based on the experience of regional experts/meteorologists who are capable of distinguishing among the different groups of the local weather conditions caused by the different depths, gradients, routes, and locations of the synoptic systems, in conjunction with knowledge of the local terrain. As applied to the EM region, the method started with the definition of the six large synoptic groups, further subdivided into a total of 19 more detailed systems. Then a small but representative (over a year) dataset of 1200 UTC daily SLP maps was classified manually, according to the depths and gradients of the SLP fields and season. Next, the corresponding H, T, U, V daily dataset (1000 hPa level, 1200 UTC) at 25 grid points over the EM (NCEP–NCAR reanalysis) was loaded into the computer program as a training set for a subsequent automatic classification for the full period of 1948–2000. The result was the 53 year daily series of the EM synoptic systems.

The series obtained allowed the analysis of the long-term climate trends. The computed trends were in agreement with the climatological history of the EM region:

1. The RST annual frequency nearly doubled since the mid-1960s, from about 50 to about 100 days. This explains a dominant decreasing trend of rainfall in many of the EM countries, along with an increase in rainfall over the southern part of the EM region. Also, the increasing tendency towards heavier daily rainfall in spite of the general decrease in the totals may be explained by the increase in the active and stormy types of RST situation.
2. We have found a drop in the annual frequency of Cyprus lows during the prolonged EM drought period of 1956–1962.
3. The annual frequency of the Cyprus low was noticed to drop slightly to 27 in 1983–98, compared with about 30 during 1967–82. The high positive correlation between the recent increase in the North Atlantic oscillation index and pressure over most of EM countries is linked to these tendencies.

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