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The prevailing summer synoptic system in Israel — Subtropical High, not Persian Trough

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ABSTRACT

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Based on analysis of 6 years of data from the European Center for Medium Range Weather Forecasts (ECMWF), it is suggested that the prevailing synoptic system in Israel during summer is the subtropical high and not the Persian Trough as frequently quoted in the literature. Vorticity variations to the west, mainly to the lee of the Turkish mountains and over the Crete region play the major role in the day-to-day variations over Israel. It is argued that these important synoptic variations through the summer are erroneously classified by both researchers and forecasters as "enhanced" or "weak" Persian Trough situations.

INTRODUCTION

The typical synoptic system controlling the weather in Israel and surroundings is generally referred to in the literature as the "Persian Trough" or "monsoonal trough", e.g., Cohen et al. (1976), Alpert et al. (1982), Dayan et al. (1988), and many others. This warm trough is an extension of the monsoon low which extends from northwest India and Pakistan through Iran and Iraq to Syria, Turkey, and the northeastern Mediterranean. The purpose of this communication is, first, to show that during summer Israel is really dominated on the average by the Subtropical Ridge and not by the Persian Trough positioned right north of it. Second, we will present evidence that summer situations that are considered enhanced Persian Troughs are in fact involved with increased cyclonicity to the west with a ridge dominance over Israel. The data/maps presented here are based on the European Center for Medium Range Weather Forecasts (ECMWF) initialized analyses over seven mandatory levels with horizontal resolution of 2.5° × 2.5° and have been described by Bengsston et al. (1988). Further details on the graphical and analyses methods employed here can be found in Alpert et al. (1990) and Neeman and Alpert (1990).

SYNOPTICS OF AVERAGE SUMMER OVER THE MEDITERRANEAN REGION

The 1000 HPa average relative vorticity for June–July–August–September 1983–1988 twice a day (0000 and 1200 UTC) is presented in Fig.1 along with the average horizontal wind vectors. As is common in synoptic meteorology only the vertical component is plotted, where $\zeta = \partial v/\partial x - \partial u/\partial y$ is the vertical component of the relative vorticity. As clearly seen, a trough of positive vorticity extends from Iran — north of the Persian Gulf — through Iraq and Syria to the northeast-

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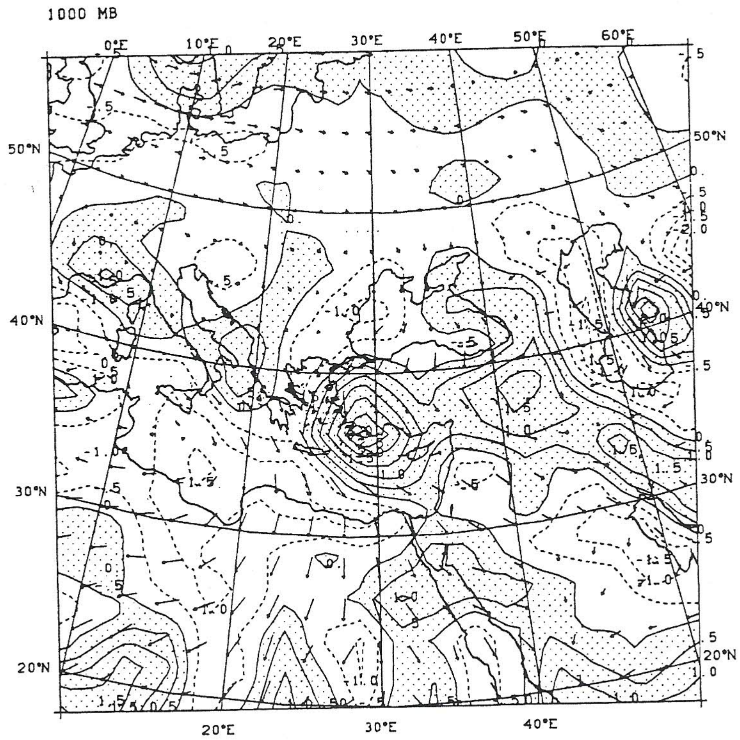

Fig. 1. The 1000 HPa average relative vorticity for June–September 1983–1988 twice a day — 0000 and 1200 UTC — along with the average horizontal wind vector. Positive vorticity is shaded. Wind vector arrows represent 15h displacements. Contour interval is $0.5 \cdot 10^{-5}$ s^{-1}. Contours are solid (dashed) for positive (negative)values.

ern Mediterranean. The maximum vortex between Cyprus and Crete was suggested by Alpert et al. (1990) to be enhanced by the lee effect of the Turkish mountains when dominated by northerly flows. A secondary maximum of vorticity extends from the Red Sea region in the south. In between the two vortex troughs the subtropical ridge from the central Mediterranean extends along the North Africain coast to Sinai. A negative vorticity maximum is found right over north Israel, Lebanon, and Syria with a maximum of $-0.5 \cdot 10^{-5}$ s^{-1}. The southern part of Israel is dominated by a narrow bridge of positive vorticity between the northern and southern maxima, but most of Israel is clearly dominated by average negative vorticity.

The vorticity values are very close to zero over Israel and day-to-day variations or even diurnal changes strongly affect the vorticity distribution, as will be discussed later. The averaged horizontal divergence field for the same period (Fig. 2), however, does show a more definite picture over Israel with a maximum of $1 \cdot 10^{-5}$ s^{-1} divergence over north Israel. Again, the maximum convergence (negative divergence), shaded in Fig. 2, is positioned to the north over Turkey and the northeast Mediterranean.

The corresponding average 1000 HPa geopotential height with a contour interval of 1 dm (~1 mb in a surface pressure map, Fig. 3) shows the common picture of the monsoonal trough from the Persian Gulf to the eastern Mediterranean with an equivalent surface pressure of 1006–7 HPa over Israel. Both the Persian trough along ~25°N to the north of Israel and the subtropical ridge can clearly be noticed. But in contrast to the trough which extends along ~35°N, the ridge along 30°N seems to turn towards the northeast (Jordan) as it approaches east Sinai.

The aforementioned figures were based upon 24 summer months (i.e., about 1440 maps/datasets) including the periferal summer months of June and September, but pictures are very similar when only July and August were included. When only one month is averaged, changes are still minor but can be noticed, as for example in Fig. 4, where the July vorticity averages for 1200 UTC only (~180 maps) are shown. (Compare Fig. 4 to Fig. 1, where June–September months were incor-

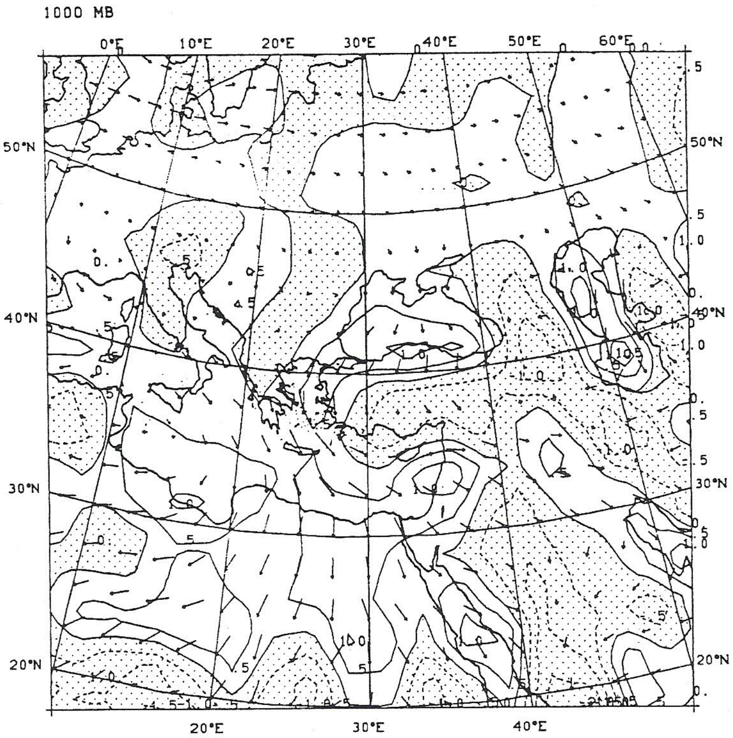

Fig. 2. As in Fig. 1 but with the average horizontal divergence ($\partial u/\partial x + \partial v/\partial y$). Shading here is for convergence (negative divergence values). Contour interval is $1{\cdot}10^{-5}\ s^{-1}$.

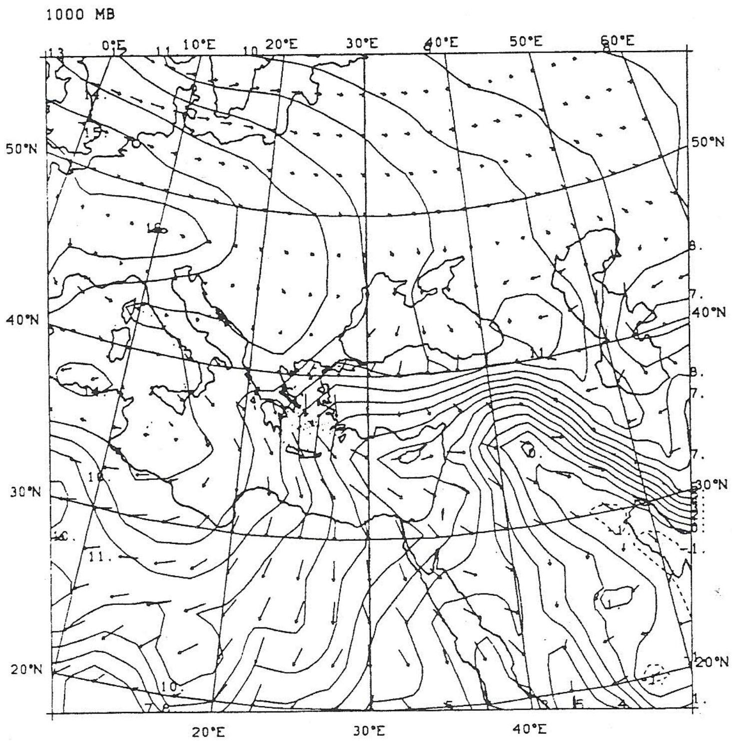

Fig. 3. The average 1000 HPa geopotential height with a contour interval 1 dm (~1 mb in a pressure map) along with wind vectors as in Fig. 1 for June–September 1983–88. Solid (dashed) contours represent positive (negative) values.

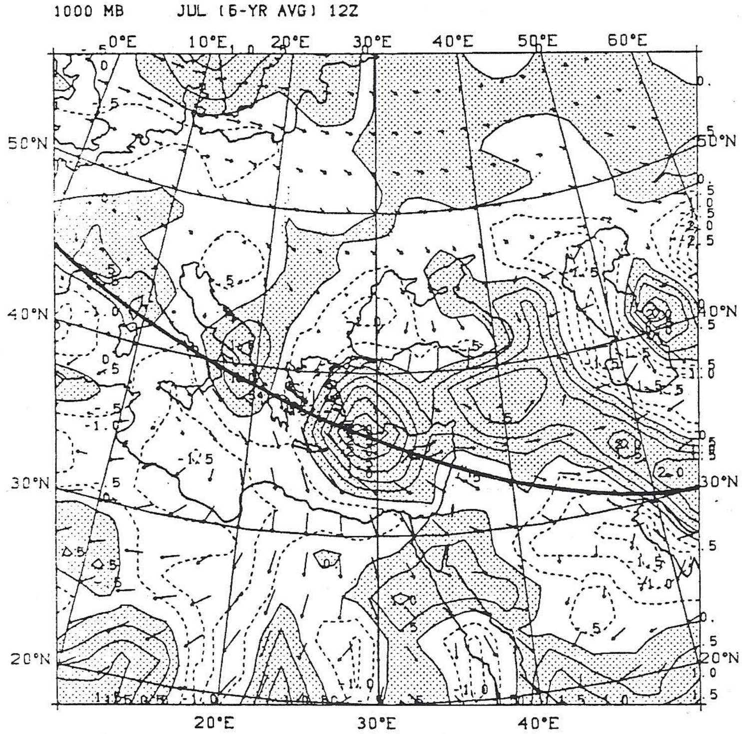

Fig. 4. As in Fig. 1 but for July 1200 UTC only.

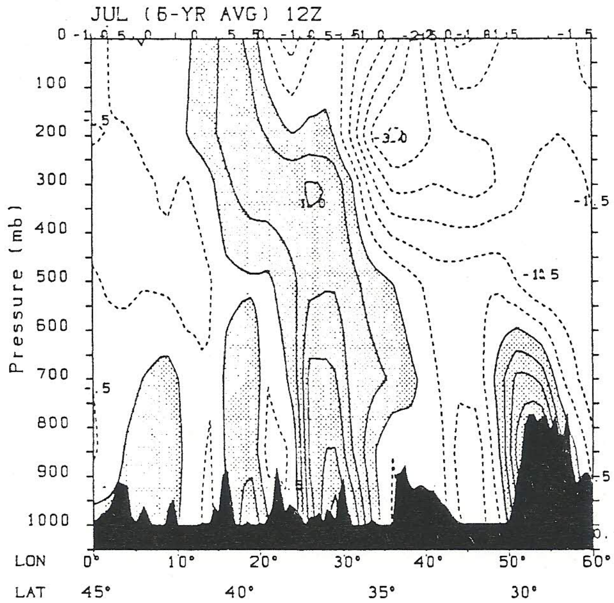

Fig. 5. Vertical distribution of average vorticity ($10^{-5}\ s^{-1}$) through the cross-section from (0°E, 45°N) to (60°E, 27.5°N) for July 1200 UTC. Averaging period consists of 6 years, 1983–1988. Positive (solid) and negative (dashed) vorticity in intervals of 0.5. Topographic altitude is indicated at the bottom with 1000 mb corresponding to zero altitude above MSL. Positive vorticity regions are shaded.

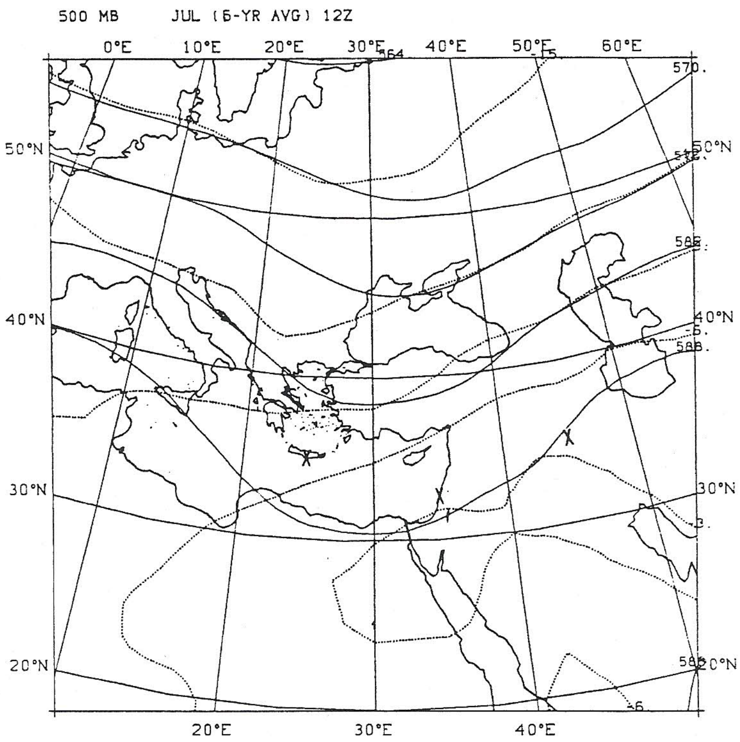

Fig. 6. The 500 HPa geopotential height (solid) with a contour interval of 12 dm for average July 1200 UTC. Dotted contours are isotherms with a 3K interval. The three points indicated by an X are referred to later in Discussion.

porated.) The vertical variation of the vorticity along a cross-section from the maximum vorticity northeast to Crete, to Lebanon, and right to the north of the Perisan Gulf (see Fig. 4) is shown in Fig. 5. The southeastern coast of the Mediterranean is clearly dominated by negative vorticity not only at the surface but through most of the troposphere. As discussed by Alpert et al. (1990), the maximum vorticity in the Crete region is related to different mechanisms near the surface (sensible and latent sea surface fluxes as well as mountain lee effects) and in the upper troposphere (jet stream). The corresponding upper-level 500 HPa geopotential height and temperature are shown in Fig. 6. One can clearly notice a weak upper-level trough over the eastern Mediterranean which is associated with a weak cold thermal trough to its west (over Greece). The region of Israel is characterized by an average temperature of −3° C and a geopotential height of 5880 m.

The significance of average day to night variations is exemplified by the August vorticity averages for 0000 and 1200 UTC in Figs. 7a and 7b, respectively. The general picture does not change, although at noon weak positive vorticity prevails over Israel. As mentioned earlier, these relatively small variations are also found in intermonthly variations; e.g., compare August to July 1200 UTC vorticity distributions in Figs. 7b and 4, respectively.

THE "ENHANCED" PERSIAN TROUGH

The summer days in Israel are frequently classified both by forecasters and scientists according to weak (A) or enhanced (B) Persian Trough conditions. In the "enhanced" Persian Trough the northwesterly surface winds are generally stronger, skies are cloudier, particularly in the morning and evening, and the inversion is higher. Dayan and Koch (1989), for instance, showed that during 1986–1988 the average Bet Dagan inversion height was 428 and 1010 m for Persian trough types A and B, respectively. Consequently, type A was more frequently involved with high pollution at the Hadera region. (The corresponding inversion heights in Hadera were 453 and 897 m based on local minisondes.)

A similar classification but with four summer cate-

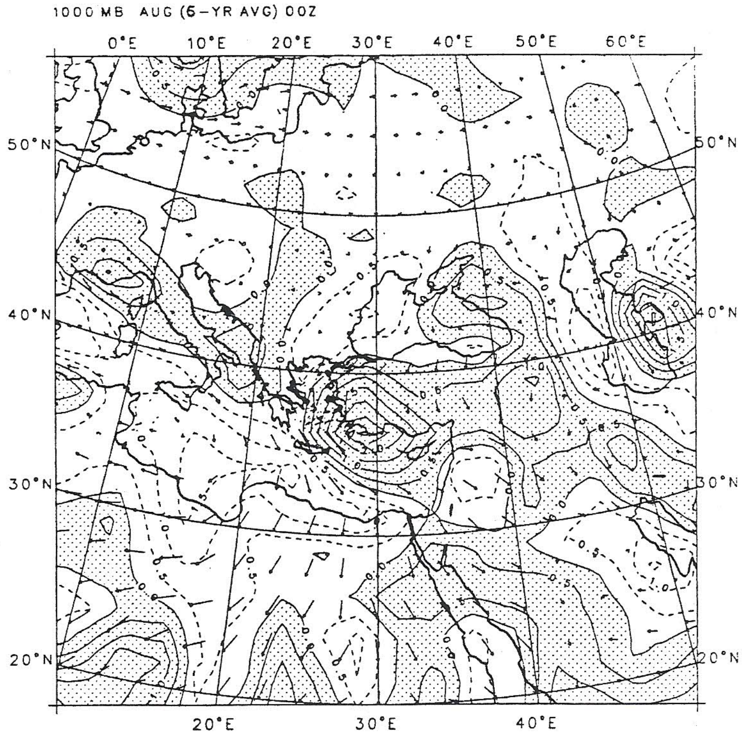

Fig. 7a. As in Fig. 1 but for August 0000 UTC only.

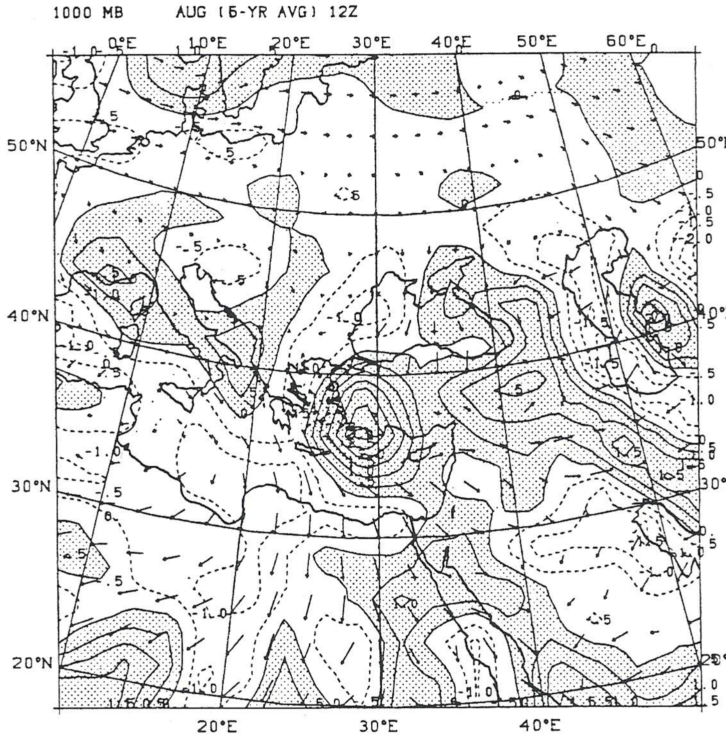

Fig. 7b. As in Fig. 1 but for August 1200 UTC only.

gories was performed by Decker and Seter for 1985 only (see Alpert et al., 1987). This classification* was based primarily on the surface pressure gradient ΔP for Cairo–Nicosia, along with other criteria. They found an "enhanced" (moderate) Persian Trough on 27 August 1985 with an inversion height of 940 m and $\Delta P = 3.3$ HPa. Hence, based on this criterion this date was identified as the strongest Persian Trough on July–August 1985. The 1000 HPa geopotential height and wind arrows for 27 August 1985 1200 UTC are shown in Fig. 8. Comparing this situation to the average summer (Fig. 3), one can notice that the northwesterly winds extend much further to the west and are stronger. Also, note the shift in the wind direction from northwesterlies in Crete for the average summer (Fig. 3) to stronger (by ~40%) west-northwesterlies for the "enhanced" Persian Trough (Fig. 8). In addition, the lowest pressure over Iraq-Syria drops by about 5 HPa.

The vorticity distribution for the "enhanced" trough in Fig. 9 however, does not indicate a vorticity increase over Israel, which is still being dominated by a center of negative vorticity. This center seems to be more isolated due to the vorticity increase over the west. The vorticity extension from the east stays nearly the same; compare Figs. 9 and 1. Therefore it is suggested that what is usually called type B or "enhanced" Persian Trough represents here a manifestation of vorticity increase to the west and not to the east, and frequently leaves Israel with negative vorticity.

THE "WEAK" PERSIAN TROUGH

In the preceding section it was illustrated that the so-called "enhanced" Persian Trough was associated with enhanced cyclonicity at the lee of the Turkish mountains and over the Aegean Sea, but not so over Syria-Iraq. Here, we present the opposite example of a "very weak" Persian Trough in order to illustrate that also in this situation a significant variability is found to the west. Figure 10 presents the 1000 HPa geopotential map for 2 September 1985 1200 UTC. This was identified in the aforementioned classification as a "very weak" Persian Trough with a *negative* pressure difference between Cairo and Nicosia ($\Delta P = -1.2$ HPa). The pressure over Israel increased by about 2HPa, i.e., from ~1006.5 HPa on the average summer map (Fig. 3) to ~1008.5 HPa (Fig. 10), with a similar increase over Iran-Iraq. The vorticity pattern in Fig. 11 does not indicate any decrease in the east (rather a slight increase) but the more significant change is again due to the vorticity maxima to the west and to the south (over Egypt). The vorticity center to the west retreats slightly to the north, disconnects from the center over Egypt–Red Sea and gives way to the subtropical ridge from North Africa to Israel. Again, Israel is dominated mainly by the subtropical ridge and strong variations in the intensity of the vorticity center are found between Turkey and Crete.

* The four categories were (i) very weak ($\Delta P \leq 0$); (ii) weak ($0 \leq \Delta P \leq 1$), (iii) moderate ($1 < \Delta P \leq 2$), (iv) strong ($\Delta P > 2$). They found frequencies of 28, 32, 31, and 9 percent respectively for 1985.

DISCUSSION

The aforementioned examples illustrate the significance of variations to the west in the summer day-to-day changes. As is well known by Mediterranean meteorologists these changes are strongly related to the upper-level trough variations. In order to get a more quantitative picture for the relative importance of variations to the west and to the east as well as in the upper versus lower level, Table 1 presents the 1985 1200 UTC geopotential height day-to-day monthly variances (square of standard deviation).

One can clearly notice that the upper-level variations at 500 HPa are larger in the west (near Crete) compared to both those in the east and in Israel. At the 1000 HPa, surface variances at the Crete region are comparable to those over North Iraq.

CONCLUSIONS

Based on the analysis of 6 years of ECMWF data over the Mediterranean we suggest that the prevailing sur-

Table 1. Geopotential height day-to-day monthly variances (m^2) for 1985, based on ECMWF data of June–September.

Level	Location	June	July	Aug.	Sept.
1000 HPa	Israel	294	229	277	284
	Crete	382	262	427	421
	N. Iraq	505	294	366	877
500 HPa	Israel	784	357	742	799
	Crete	1171	1051	944	1777
	N. Iraq	804	554	445	816

The three points are Israel (32.5°N, 35°E), Crete (35°N, 25°E), and North Iraq (35°N, 45°E) and are indicated on Fig. 6.

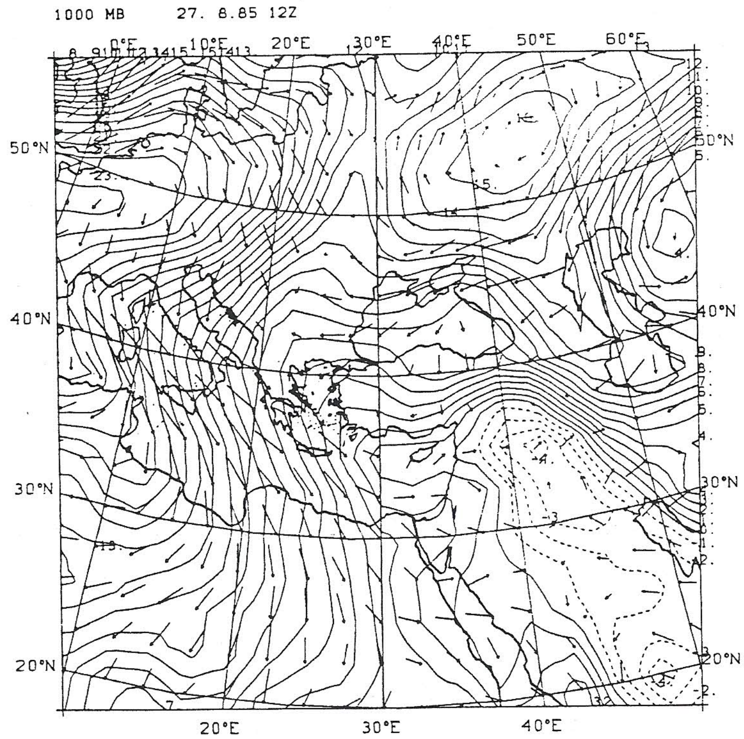

Fig. 8. As in Fig. 3 but 1000 HPa geopotential height and wind arrows for 27 August 1985 1200 UTC — "enhanced" Persian Trough.

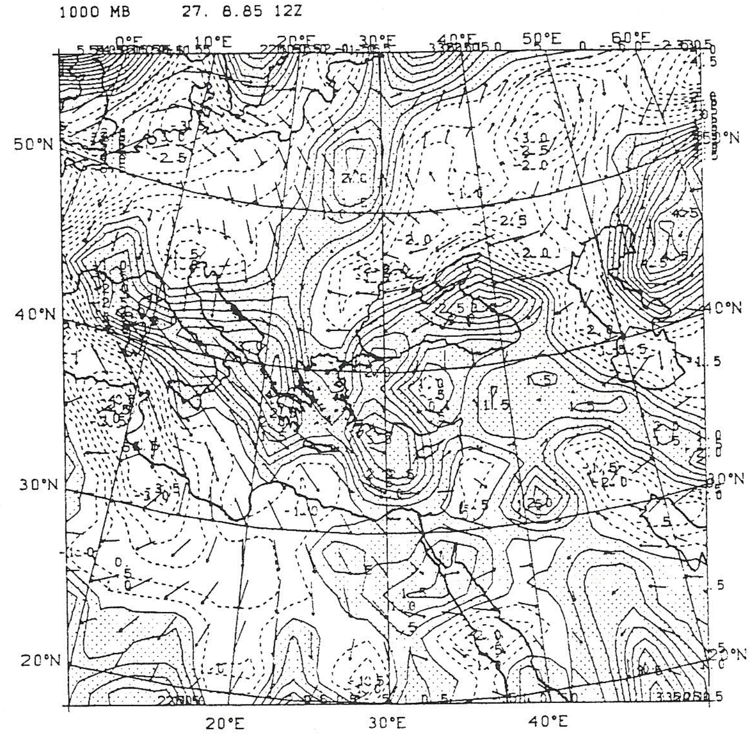

Fig. 9. The vorticity and wind arrows as in Fig. 1 but for 27August 1985 1200 UTC — the "enhanced" Persian Trough.

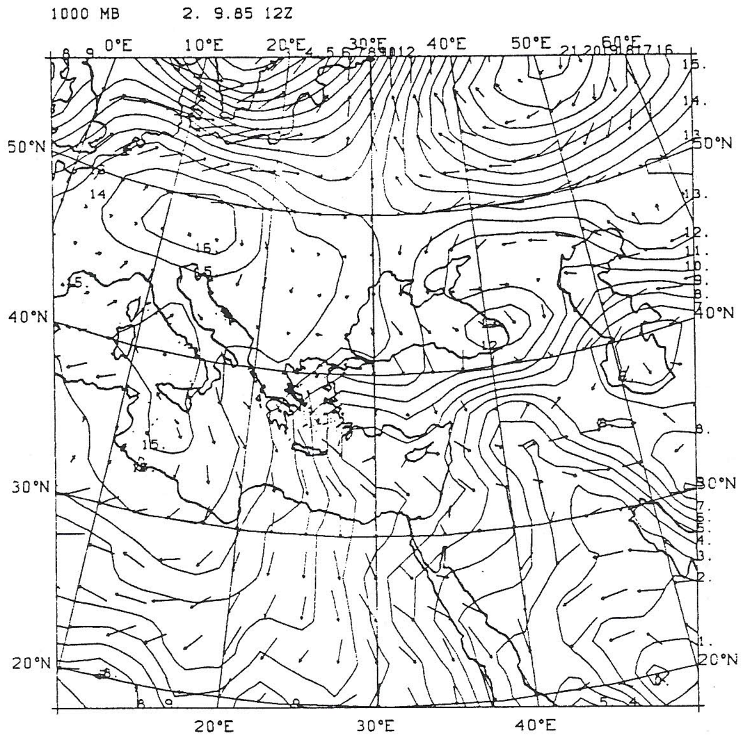

Fig. 10. As in Fig. 8 but for 2 September 1985 1200 UTC — the "weak" Persian Trough.

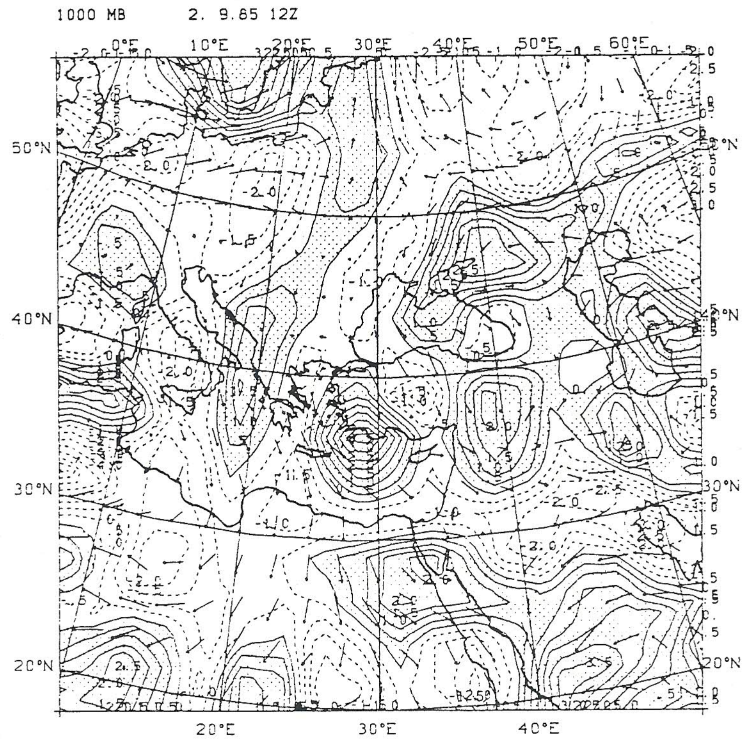

Fig. 11. As in Fig. 9 but for 2 September 1985 1200 UTC — the "weak" Persian Trough.

face synoptic system in Israel during summer is the subtropical high and not the Persian Trough as frequently quoted in the literature. This is expressed by both negative vorticity and positive divergence found for the average of 1440 day and night datasets during June to September 1983–1988. Similar results are obtained for only monthly averages with minor changes.

It is illustrated in two cases for 1985 that the "enhanced" and "weak" Persian trough conditions referred to in the literature are associated with strong variations in the vorticity pattern above the Mediterranean *west* of Israel and smaller changes of the monsoonal trough from the Persian Gulf to Syria in the east. In summary, this study emphasizes some drawbacks of the standard classification of day-to-day variations of the synoptic situation over Israel during summer as "enhanced" or "weak" Persian trough situations.

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