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Temporal and Spatial Trends of Temperature Patterns in Israel

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With 9 Figures

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Summary

Daily maximum and minimum temperatures from 40 stations in Israel were analyzed to detect long-term trends and changes in temporal and spatial distribution patterns during the second half of the 20th Century. The trend analysis, reveals a rather complex changing pattern, with a significant decreasing trend of both the daily maximum and minimum temperature, during the cool season, and an increasing trend during the warm season.

The seasonal temperature range exhibits an increasing trend: the summers have become warmer while the winters have become colder. The increase of the minimum summer temperature is more pronounced than the increase of the maximum temperature, while the decrease of the maximum temperature in winter is greater than the decrease of the minimum, thus resulting in a significant decline of the air temperature diurnal range in both seasons.

It appears that the frequency of occurrence of extreme temperature events, with lower winter and higher summer temperatures, has increased.

On an annual basis, there seems to be almost no temporal trends in minimum and maximum temperatures since the changes in winter and summer show an opposite tendencey.

1. Introduction

There seems to be a general agreement among many scientists that global surface temperature has been increasing over the past 100 years by 0.3–0.6 °C, presumably due to the enhanced greenhouse effect, as a result of the increasing concentrations of carbon dioxide and other greenhouse gases into the atmosphere. This warming trend, however, has exhibited considerable temporal and spatial variabilities (e.g., Jones and Wigley, 1986; Jones et al., 1986; Hansen and Lebedeff, 1987; Houghton et al., 1995).

Some climate modeling results indicate that global warming should be most pronounced during the cold season over higher latitudes (e.g., Robock, 1983; Ingram et al., 1989). In fact, an upward temperature trend in the Northern hemisphere, mostly at higher latitudes, during the winter and spring seasons, was noticed in studies, by Gutzler et al. (1988), Karl et al. (1993) and Folland et al. (1990, 1992). This upward trend during the cold season seems to be dominated rather by regional scale features, whereas the warm season anomalies tend to be of the same tendency all over the hemisphere (Wallace et al., 1995a, 1995b; Hurrel and Van Loon, 1997).

The importance of climatic studies on a regional scale by analyzing local and regional long-term temperature records, is thus abvious. Unfortunately, most of these studies were carried out primarily in North America, Europe and Australia, due to the availability of climatic data from relatively dense station networks and long term records. Scarcity of relevant data records resulted in relatively fewer studies at the more marginal areas at the lower latitudes. This is obviously the case in the region of the Middle East in general and the Eastern Mediterranean in particular. Some studies carried out in this region are based on a relatively small number of stations, with seemingly ambiguous or non-conclusive results (e.g., Jaffe, 1991; Shalit, 1992; Metaxas et al., 1991; Sahamanuglou and Makrogiannis, 1992; Nasrallah and Balling, 1993).

The Mediterranean region forms a transitional zone between the mid-latitudes of Western and Central Europe and the arid regions of North Africa and the Middle East, with the inland Mediterranean sea in between. Israel is located at the Eastern part of the Mediterranean, influenced by the westerlies in winter, and the blocking subtropical high during the dry summer season. Extreme climatic gradients from the North to the South, and from the West to the East are typical for this region. This geo-climatic location of the Eastern Mediterranean makes it an appealing location for tracing and monitoring air temperature trends, which might be affected by global, regional and local factors. As Segal et al. (1994), have shown recently, by using a regional numerical model, and a CO_2 doubling scenario, the aridity marginal area over the Eastern Mediterranean may result in shifting northward. These results may be indicative of the relatively high sensitivity of this region to the global warming effect.

Previous studies by Ben-Gai et al. (1993, 1994, 1998b), have revealed considerable changes in the temporal and spatial distribution of precipitation patterns, which were related partly to extreme changes in land uses, which took place in Israel during the last 30 years. It is conceivable that such changes in land uses might have affected also the temperature patterns, in addition to the possible influence of global and regional factors. Land uses are in control of water vapor amount, rate of albedo and the availability of net radiation (Alpert and Mandel, 1986; Ruschy et al., 1991; Ben-Gai, 1998a).

In the present study advantage will be taken of the relatively dense network of stations with long-term records of maximum and minimum temperature available in Israel. Revealing the changing temporal and spatial patterns of maximum and minimum temperature in Israel may provide some clues as to how global, regional and local factors could have effected the temperature regime in Israel, as well as in other marginal areas, with all its impacts on human activities, i. e. agricultural production and energy management.

2. Database and Methodology

The database for the present study consists of daily maximum and minimum temperature values (Tmax and Tmin) from 40 stations of the Israel Meteorological Service station network (Fig. 1). The data cover a period of 31 years (1964–1994).

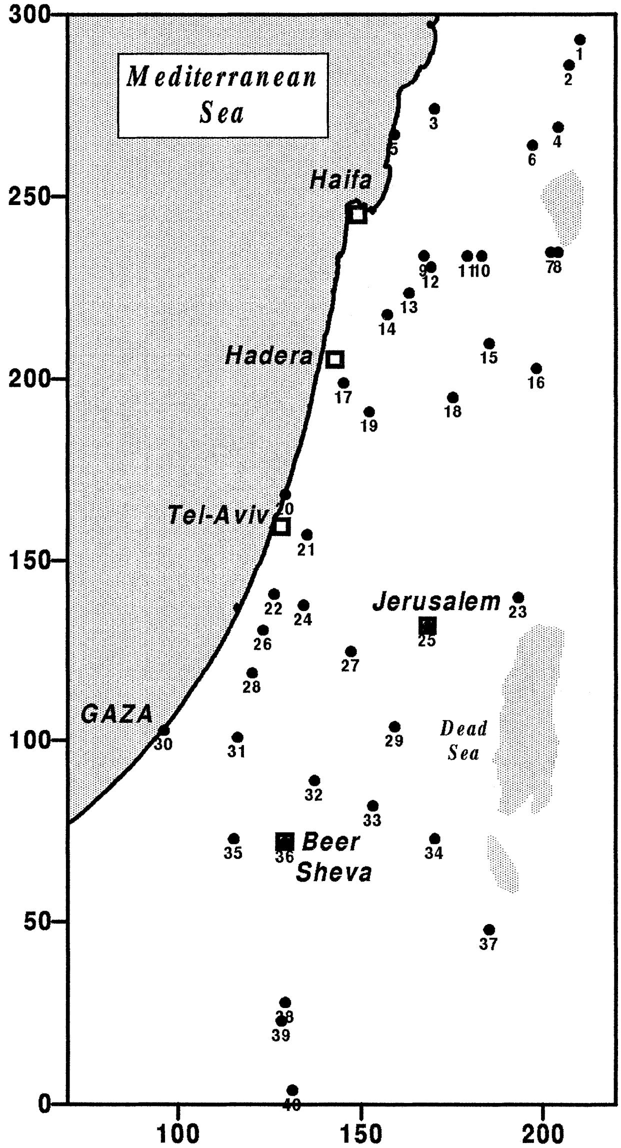


Fig. 1. Spatial distribution of 40 temperature stations over Israel

Temperature stations that changed location during the period of record were not included in the database. Figure 1 shows the spatial distribution of the 40 stations used in the present study, numbered from North to South. It should be stated that the stations spread over quite different climatic regions, even though the total N-S distance is less than 300 km. Stations 1–20 have over 500 mm normal rainfall with a temperate climate, while stations 35–40 have below 200 mm and are in an arid (semi-arid) zone.

Trend analyses were carried out on the daily temperature data from each station, and for each month, by regressing the Tmax, Tmin and diurnal range values with time. The slopes of the fitted serial linear regression lines were then tested as to their significance. The Spearman and Kendall rank correlation coefficients were also calculated to test the significance of the trends. All calculations were carried out by using the STATGRAPHIC statistical Software Package, Version 7.0 (Manugistics, Inc., Rockville, MD 20852–4999).

The maps in this study were plotted by using the SURFARE software package, version 6, by applying the kriging method using a linear variograme model.

Some important climatic changes may be revealed also from temporal and spatial changes in the frequency distribution patterns, i.e. changes in location and in scale parameter (which are equivalent, in case of a Gaussian distribution, to the mean and standard deviation, respectively). Such changes may indicate changes in extreme temperature events frequency.

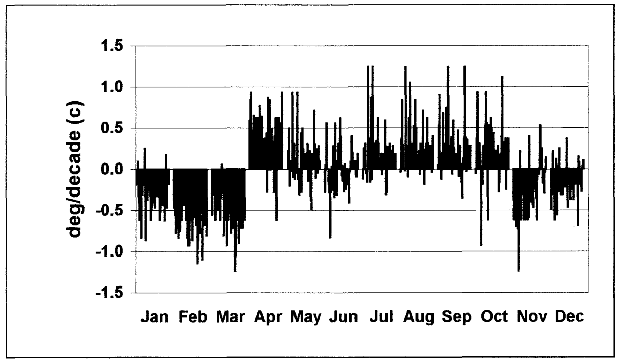
To examine these changes, the temperature data were divided into two equal periods: 1964–1979 and 1980–1994. Normal frequency distributions were fitted to the data, corresponding to the two selected periods. The results are discussed in terms of changes of the critical values of the distributions, i.e. changes in the 0.1, 0.5 and 0.9 percentiles of the temperature distribution between the selected periods.

3. Results

3.1 Trend Analyses

Most of the results of trend analyses, expressed by the slopes of the regression lines fitted to the daily Tmax, Tmin and diurnal range (DR) as function of time t, since 1964, at 40 stations, are statistically significant at the 5% confidence level (Tab. 1a, 1b, 1c). The significance of the trends is confirmed also by the Spearman and Kendall serial rank correlation method (Kendall and Ord, 1990).

a



b

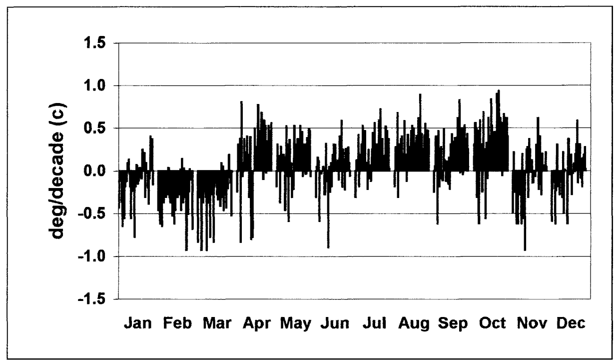


Fig. 2. Histograms of the slopes of the linear regression in (a) maximum and (b) minimum temperature (°C per decade), 1964–1994

Figure 2a,b depicts the histograms of the slopes of the linear trends in maximum and minimum temperature, in °C per decade, for all stations and all months of the year. A general and clearly defined seasonal pattern is revealed. During the cool season, starting from November to March, most of the stations exhibit a generally decreasing trend in both Tmax and Tmin, with a median value of −0.38 °C/decade for Tmax and −0.12 °C/decade for Tmin. If only the stations showing significant trends are considered, the corresponding median values of the negative trends are −0.5 °C/decade for Tmax and −0.28 °C/decade for Tmin.

On the other hand, a positive, though less coherent, trend is evident during the warm

Table 1. *Values of Temperature Trends from 1964–1994 at Different Significant Levels. (a) For Maximum Values; (b) For Minimum Values; (c) for Range Values. Temperature Stations are Sorted from North to South. The Significant Levels Around 0.10 and 0.05 of the Trends are Marked by Bold and Bold-Underlined Figures, Respectively*

Table 1a.

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1	Dafna	−0.19	**−0.47**	**−0.56**	**0.59**	0.00	**−0.28**	−0.12	−0.03	0.05	−0.05	**−0.62**	**−0.50**	−0.18
2	Kefar Blum	−0.12	**−0.56**	**−0.25**	**0.84**	0.22	0.05	**0.25**	**0.37**	**0.53**	**0.37**	**−0.31**	**−0.31**	0.09
3	Elon	0.09	**−0.78**	**−0.31**	**0.93**	**0.50**	**0.56**	**0.25**	**0.84**	**0.90**	**0.93**	**−0.28**	0.22	0.32
4	Ayyelet Ha Shahar	**−0.40**	**−0.71**	**−0.20**	**0.37**	−0.20	0.00	**0.31**	**0.29**	0.18	0.02	**−0.70**	**−0.29**	−0.11
5	Nahariyya	**−0.62**	**−0.62**	**−0.62**	**0.47**	0.09	**−0.19**	−0.05	0.00	**−0.12**	**0.31**	**−0.62**	−0.62	−0.22
6	Har Kenaan	**−0.26**	**−0.84**	**−0.50**	**0.65**	−0.02	**−0.29**	−0.16	−0.02	**0.19**	0.19	**−0.73**	**−0.31**	−0.17
7	Kinneret	**−0.84**	−0.37	−0.12	0.15	**0.93**	**−0.84**	**1.24**	**1.24**	**0.68**	**−0.93**	**−1.24**	0.12	0.00
8	Deganya Alef	**−0.31**	**−0.74**	**−0.50**	**0.40**	−0.09	**−0.28**	0.02	0.06	0.03	0.03	−0.09	−0.56	−0.17
9	Newe Yaar	0.00	−0.19	−0.09	**0.62**	**0.31**	0.03	**0.37**	**0.28**	**0.31**	−0.19	0.22	0.03	0.14
10	Tavor Agr. School	**−0.19**	**−0.62**	**−0.31**	**0.62**	−0.12	**−0.25**	**−0.16**	−0.09	**0.05**	**0.28**	**−0.62**	**−0.28**	−0.14
11	Nazareth Up. Town	0.25	−0.22	**−0.62**	**0.62**	0.12	0.28	0.87	**0.62**	**0.74**	0.22	−0.31	0.25	0.24
12	Ramat Dawid	−0.87	**−0.43**	**−0.35**	**0.60**	−0.04	−0.34	**−0.12**	0.07	**0.28**	**0.52**	**−0.30**	−0.10	−0.09
13	Mishmar Ha Emeq	−0.03	**−0.03**	0.06	**0.78**	**0.93**	**0.56**	**1.24**	**1.05**	**1.24**	0.93	**−0.62**	−0.31	0.48
14	Even Yizhaq	**−0.37**	**−0.06**	**−0.28**	**0.56**	−0.12	0.09	**0.31**	**0.31**	**0.28**	**0.56**	**−0.53**	**−0.31**	0.04
15	Biet Qad	**−0.25**	**−0.62**	**−0.81**	0.00	−0.31	**−0.31**	**0.22**	0.00	0.06	**−0.62**	**−0.62**	**−0.31**	−0.30
16	Tirat Zevi	**−0.25**	**−0.47**	**−0.08**	**0.64**	−0.05	0.08	0.06	**0.13**	**0.24**	**0.16**	**−0.36**	**−0.19**	−0.01
17	Ein Ha Horesh	−0.06	**−0.84**	**−0.06**	0.12	**0.43**	**0.31**	**0.34**	**0.52**	**0.39**	**0.53**	−0.12	−0.09	0.12
18	Meithalun	−0.62	**−0.93**	**−0.62**	0.31	−0.28	0.00	0.16	0.09	−0.06	0.06	**−0.62**	**−0.22**	−0.23
19	Tulkarm	−0.50	**−0.93**	**−0.93**	0.37	**0.50**	**0.62**	**0.62**	**0.84**	**0.59**	**0.62**	**−0.59**	−0.22	0.08
20	Tel Aviv Sede-Dov	**−0.43**	**−0.62**	**−0.40**	0.12	0.25	0.40	**0.31**	**0.50**	**0.25**	**0.50**	0.40	0.37	0.14
21	Bet Dagan	**−0.40**	**−0.62**	**−0.62**	**0.43**	0.16	−0.08	**0.12**	**0.16**	**0.14**	**0.25**	**−0.40**	**−0.47**	−0.11
22	Yavne Kvuza	−0.12	**−0.43**	**−0.53**	**−0.28**	0.19	**−0.14**	0.05	**0.09**	**0.19**	**0.43**	−0.10	**−0.19**	−0.07
23	Jericho	**−0.47**	**−0.87**	**−0.47**	**0.87**	0.03	0.04	**0.19**	**0.22**	0.00	0.19	−0.40	−0.09	−0.06
24	Mazkeret Batya	**−0.30**	**−0.59**	**−0.78**	0.20	0.06	**−0.28**	−0.07	−0.06	0.03	0.14	**−0.43**	**−0.37**	−0.20
25	Jerusalem	−0.12	**−0.56**	**−0.53**	**0.84**	**0.31**	0.06	**0.19**	**0.31**	**0.47**	**0.22**	**−0.47**	**−0.24**	0.04
26	Hazor Ashdod	**−0.33**	**−0.58**	**−0.71**	0.00	−0.14	**−0.24**	0.07	**0.07**	−0.08	0.02	−0.16	−0.12	−0.18
27	Beit Jimal	−0.12	**−0.67**	**−0.49**	**0.49**	0.14	0.01	**0.18**	**0.23**	**0.28**	0.18	−0.23	−0.20	−0.02
28	Negba	**−0.31**	**−0.62**	**−0.65**	**0.34**	0.22	**−0.19**	**0.59**	0.71	0.06	**0.28**	**−0.34**	**−0.37**	−0.02
29	Hebron	**−0.62**	**−1.15**	**−1.24**	**0.25**	−0.37	−0.12	−0.31	0.00	−0.16	−0.28	**−0.62**	0.00	−0.38
30	Gaza	**−0.52**	**−0.87**	**−1.05**	**−0.28**	**−0.48**	**−0.41**	**−0.28**	**−0.19**	**−0.35**	−0.16	−0.12	−0.13	−0.40
31	Dorot	**−0.40**	**−0.59**	**−0.62**	0.40	0.19	−0.03	**0.27**	**0.23**	**0.13**	**0.17**	−0.06	−0.18	−0.04
32	Lahav	**−0.43**	**−0.78**	**−0.62**	**0.62**	0.00	0.09	**0.25**	**0.31**	**0.37**	**0.40**	−0.06	−0.16	0.00
33	Yattir	−0.31	−0.34	**−0.90**	**−0.62**	**0.71**	**0.40**	**0.31**	**0.62**	**1.24**	**1.12**	**0.53**	**−0.68**	0.17
34	Arad	−0.03	**−0.48**	**−0.39**	**0.62**	**0.30**	**0.20**	**0.20**	**0.32**	**0.38**	**0.32**	0.01	0.16	0.13
35	Hazerim Kibbuz	**−0.63**	**−1.10**	**−0.71**	0.30	−0.11	0.02	0.09	0.07	−0.03	0.25	0.25	0.08	−0.13
36	Beer Sheva	−0.16	**−0.43**	**−0.55**	**0.62**	0.24	0.02	**0.22**	**0.21**	**0.36**	**0.33**	−0.17	−0.19	0.04
37	Sedom Pans	**0.17**	−0.16	−0.22	**0.56**	**0.19**	0.09	**0.28**	**0.28**	**0.28**	**0.37**	−0.06	**−0.22**	0.13
38	Sede Boqer	**−0.47**	**−0.67**	**−0.71**	0.25	−0.04	−0.07	0.11	0.08	0.06	**−0.24**	**−0.29**	**−0.27**	−0.19
39	Avedat	0.00	**−0.31**	**−0.50**	**0.40**	0.28	−0.09	0.09	−0.03	0.15	0.16	−0.03	0.03	0.01
40	Rekhes Ramon	−0.18	**−0.81**	**−0.62**	**0.93**	0.10	0.19	**0.19**	**0.40**	**0.28**	0.37	0.14	0.11	0.09
	Average	−0.29	−0.59	−0.51	0.42	0.13	−0.01	0.22	0.28	0.26	0.22	−0.29	−0.18	**−0.03**

Table 1b.

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1	Dafna	**−0.43**	**−0.47**	**−0.84**	**−0.25**	**−0.19**	**−0.31**	**−0.31**	**−0.19**	**−0.25**	0.00	**−0.50**	**−0.59**	−0.36
2	Kefar Blum	−0.06	−0.12	−0.16	**0.31**	**0.31**	0.05	**0.12**	0.28	0.05	**0.31**	**0.22**	**−0.21**	0.09
3	Elon	−0.11	**−0.62**	−0.31	0.31	0.06	0.16	0.03	**0.28**	**0.40**	**0.56**	−0.25	−0.12	0.03
4	Ayyelet Ha Shahar	**−0.37**	−0.16	−0.06	**0.38**	0.17	0.11	**0.42**	**0.68**	**0.28**	**0.49**	−0.24	−0.10	0.13
5	Nahariyya	**−0.65**	**−0.65**	**−0.93**	**−0.84**	**−0.37**	**−0.59**	**−0.19**	**−0.31**	**−0.62**	**−0.31**	−0.62	**−0.62**	−0.56
6	Har Kenaan	−0.07	−0.37	−0.12	**0.81**	**0.28**	0.00	**0.18**	**0.30**	**0.47**	**0.47**	−0.40	−0.23	0.11
7	Kinneret	**−0.56**	**−0.37**	**−0.37**	−0.06	0.12	−0.03	0.19	**0.31**	−0.19	**−0.62**	−0.62	**0.31**	−0.16
8	Deganya Alef	**−0.19**	**−0.31**	**−0.25**	**0.09**	**0.19**	0.00	**0.31**	**0.37**	**0.25**	**0.59**	−0.06	**−0.19**	0.07
9	Newe Yaar	−0.12	0.00	−0.06	**0.37**	**0.19**	0.05	**0.53**	**0.40**	**0.28**	0.16	−0.28	−0.16	0.11
10	Tavor Agr. School	−0.12	**−0.31**	**−0.31**	**0.22**	0.16	0.03	**0.12**	**0.19**	−0.09	**0.31**	−0.25	**−0.28**	−0.03
11	Nazareth Up. Town	0.09	−0.28	−0.93	0.05	**−0.47**	**−0.28**	0.12	**0.19**	−0.11	**−0.25**	−0.62	−0.12	−0.22
12	Ramat Dawid	0.13	0.04	−0.01	**0.40**	**0.52**	**0.32**	**0.46**	**0.58**	**0.49**	**0.69**	0.20	−0.07	0.31
13	Mishmar Ha Emeq	−0.03	0.03	**−0.37**	0.19	**0.31**	−0.12	0.06	0.09	0.12	0.06	−0.56	**−0.31**	−0.04

Table 1b (*continued*)

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
14	Even Yizhaq	−0.19	−0.31	−0.25	0.16	−0.06	0.00	0.09	0.19	0.04	0.25	−0.25	0.22	−0.01
15	Biet Qad	−0.56	−0.37	−0.78	−0.31	−0.59	−0.90	−0.22	−0.12	−0.12	−0.56	−0.93	−0.50	−0.50
16	Tirat Zevi	−0.24	−0.24	−0.07	0.39	0.37	0.05	0.24	0.42	0.11	0.33	−0.02	0.02	0.11
17	Ein Ha Horesh	0.00	−0.53	−0.28	−0.81	−0.06	−0.25	−0.09	0.13	−0.16	−0.09	0.25	0.00	−0.16
18	Meithalum	−0.12	−0.47	−0.25	−0.31	0.09	0.09	0.06	0.16	0.16	0.62	0.28	0.00	0.03
19	Tulkarm	−0.78	−0.62	−0.84	−0.78	−0.31	−0.19	−0.12	0.28	−0.22	0.16	−0.31	−0.62	−0.36
20	Tel Aviv Sede-Dov	−0.19	−0.47	−0.19	0.00	−0.22	0.19	0.25	0.47	0.31	0.40	0.37	0.37	0.11
21	Bet Dagan	0.07	−0.02	−0.03	0.50	0.53	0.31	0.44	0.53	0.43	0.84	0.25	−0.04	0.32
22	Yavne Kvuza	0.06	−0.09	−0.13	0.28	0.31	0.19	0.34	0.43	0.34	0.53	−0.02	0.12	0.20
23	Jericho	−0.16	−0.31	−0.28	0.22	0.31	0.31	0.56	0.50	0.22	0.37	0.12	0.19	0.17
24	Mazkeret Batya	−0.11	−0.22	−0.33	0.00	0.09	0.02	0.16	0.19	0.10	0.37	−0.14	−0.28	−0.01
25	Jerusalem	0.04	−0.28	−0.12	0.78	0.37	0.09	0.31	0.32	0.39	0.45	−0.14	−0.03	0.18
26	Hazor Ashdod	−0.07	0.02	−0.04	0.20	0.34	0.12	0.31	0.41	0.13	0.33	−0.02	0.08	0.15
27	Beit Jimal	−0.09	−0.47	−0.41	0.22	0.11	−0.10	0.19	0.19	0.11	0.19	−0.06	−0.01	−0.01
28	Negba	0.25	0.14	0.09	0.47	0.53	0.40	0.59	0.62	0.62	0.90	0.30	0.20	0.42
29	Hebron	0.09	−0.37	−0.31	0.68	0.06	0.06	0.25	0.62	0.47	0.62	0.09	0.31	0.21
30	Gaza	0.21	0.03	0.06	0.43	0.45	0.59	0.72	0.89	0.83	0.94	0.62	0.59	0.53
31	Dorot	−0.31	−0.31	−0.47	−0.10	−0.06	−0.19	0.04	0.16	−0.02	0.19	−0.22	−0.14	−0.12
32	Lahav	0.09	−0.05	0.00	0.59	0.16	0.25	0.37	0.43	0.47	0.62	0.40	0.03	0.28
33	Yattir	−0.02	−0.93	−0.28	0.53	0.31	0.12	0.03	0.25	0.50	0.56	−0.16	0.31	0.10
34	Arad	−0.20	−0.50	−0.43	−0.02	−0.04	−0.22	0.09	0.10	−0.04	−0.05	−0.28	−0.09	−0.14
35	Hazerim Kibbuz	−0.38	−0.51	−0.03	0.20	−0.03	0.26	0.17	0.42	0.17	0.39	0.20	0.14	0.08
36	Beer Sheva	−0.09	−0.24	−0.21	0.34	0.38	0.25	0.52	0.55	0.53	0.66	0.06	−0.19	0.21
37	Sedom Pans	0.40	0.02	0.19	0.53	0.37	0.16	0.47	0.43	0.37	0.56	0.04	0.11	0.30
38	Sede Boqer	0.04	−0.10	−0.07	0.29	0.49	0.27	0.34	0.47	0.36	0.62	0.06	0.19	0.25
39	Avedat	0.37	0.00	−0.14	0.47	0.47	0.09	0.37	0.47	0.43	0.62	0.22	0.28	0.30
40	Rekhes Ramon	−0.16	−0.68	−0.53	0.56	−0.06	−0.06	0.03	0.37	0.25	0.40	0.04	0.02	0.01
	Average	−0.11	−0.29	−0.27	0.19	0.14	0.03	0.21	0.33	0.20	0.34	−0.08	−0.04	**0.05**

Table 1c.

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1	Dafna	0.22	0.00	0.28	0.84	0.19	0.12	0.22	0.16	0.31	0.00	−0.28	0.09	0.18
2	Kefar Blum	−0.06	−0.43	−0.09	0.50	−0.09	0.00	0.12	0.12	0.47	−0.19	−0.81	−0.09	−0.05
3	Elon	0.22	0.06	−0.03	0.71	0.40	0.31	0.22	0.53	0.47	0.43	−0.03	0.31	0.30
4	Ayyelet Ha Shahar	−0.03	−0.55	−0.15	0.00	−0.36	−0.11	−0.07	−0.38	−0.10	−0.46	−0.45	−0.19	−0.24
5	Nahariyya	−0.03	−0.11	0.25	1.30	0.50	0.37	0.12	0.28	0.50	0.71	0.09	−0.06	0.33
6	Har Kenaan	−0.18	−0.47	−0.34	−0.13	−0.29	−0.28	−0.34	−0.31	−0.28	−0.28	−0.31	−0.08	−0.27
7	Kinneret	−0.25	0.00	−0.25	1.55	−0.62	0.93	0.93	0.84	9.30	−0.19	−0.40	−0.19	0.97
8	Deganya Alef	−0.12	−0.40	−0.22	0.28	−0.28	−0.28	−0.31	−0.31	−0.22	−0.31	−0.78	−0.37	−0.28
9	Newe Yaar	0.16	−0.19	−0.03	0.40	0.12	0.00	−0.16	−0.12	0.03	−0.31	0.06	0.19	0.01
10	Tavor Agr. School	−0.03	−0.31	−0.05	0.40	−0.28	−0.28	−0.25	−0.28	0.16	−0.03	−0.40	0.00	−0.11
11	Nazareth Up. Town	1.55	0.53	0.31	0.62	0.59	0.56	0.62	0.47	0.62	0.47	0.31	0.31	0.58
12	Ramat Dawid	−0.22	−0.47	−0.34	0.16	−0.56	−0.66	−0.58	−0.52	−0.21	−0.16	−0.50	−0.03	−0.34
13	Mishmar Ha Emeq	0.00	0.00	0.47	0.56	0.62	0.62	0.12	0.93	1.09	0.04	−0.06	0.00	0.45
14	Even Yizhaq	−0.19	−0.31	−0.03	0.40	0.19	0.09	0.22	0.11	0.25	0.31	−0.25	−0.09	0.06
15	Biet Qad	0.31	−0.22	−0.03	0.31	0.25	0.59	0.47	0.09	0.22	−0.09	0.19	0.16	0.19
16	Tirat Zevi	−0.01	−0.23	0.00	0.24	−0.42	−0.40	−0.19	−0.30	0.13	−0.17	−0.34	−0.20	−0.16
17	Ein Ha Horesh	−0.09	−0.28	−0.37	0.93	0.50	0.62	0.43	0.37	0.53	0.62	−0.37	−0.11	0.23
18	Meithalun	−0.50	−0.40	−0.31	0.62	−0.37	−0.09	−0.22	−0.06	−0.22	−0.62	−0.93	−0.22	−0.28
19	Tulkarm	0.25	−0.31	−0.11	1.24	0.93	0.93	0.62	0.53	0.81	0.47	−0.28	0.40	0.46
20	Tel Aviv Sede-Dov	−0.22	−0.16	−0.22	0.16	0.03	0.19	0.06	0.03	−0.03	0.06	0.04	0.00	0.00
21	Bet Dagan	−0.47	−0.62	−0.63	−0.05	−0.37	−0.42	−0.31	−0.38	−0.30	−0.60	−0.70	−0.43	−0.44
22	Yavne Kvuza	−0.19	−0.34	−0.37	0.00	−0.12	−0.34	−0.31	−0.34	−0.19	−0.12	−0.09	−0.06	−0.21
23	Jericho	−0.28	−0.53	−0.19	0.62	−0.31	−0.28	−0.37	−0.28	−0.22	−0.19	−0.53	−0.31	−0.24
24	Mazkeret Batya	−0.16	−0.37	−0.43	0.20	−0.03	−0.28	−0.22	−0.26	−0.12	−0.25	−0.29	−0.11	−0.19
25	Jerusalem	−0.16	−0.29	−0.42	0.05	−0.05	−0.05	−0.11	0.01	0.11	−0.22	−0.33	−0.21	−0.14
26	Hazor Ashdod	−0.25	−0.60	−0.67	−0.20	−0.49	−0.36	−0.24	−0.33	−0.21	−0.31	−0.13	−0.19	−0.33
27	Beit Jimal	−0.02	−0.16	−0.08	0.26	0.02	0.15	−0.12	0.04	0.18	−0.01	−0.16	−0.19	−0.01
28	Negba	−0.59	−0.78	−0.74	−0.12	−0.31	−0.56	−0.65	−0.31	−0.31	−0.59	−0.62	−0.59	−0.51
29	Hebron	−0.62	−0.62	−0.62	−0.40	−0.43	−0.19	−0.59	−0.62	−0.62	−0.93	−0.62	−0.40	−0.56

Table 1c (*continued*)

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
30	Gaza	**−0.74**	**−0.92**	**−1.12**	**−0.71**	**−0.94**	**−1.00**	**−1.02**	−1.09	**−1.18**	**−1.10**	**−0.76**	**−0.72**	−0.94
31	Dorot	−0.08	**−0.25**	−0.17	**0.50**	**0.27**	0.16	0.22	0.07	**0.15**	**−0.01**	0.14	−0.03	0.08
32	Lahav	**−0.53**	**−0.62**	**−0.62**	0.00	−0.16	−0.16	−0.12	−0.09	−0.12	**−0.31**	**−0.50**	**−0.43**	−0.30
33	Yattir	**−0.31**	0.00	**−0.50**	0.19	0.28	0.28	**0.59**	1.15	**0.59**	−0.02	**−0.50**	**−0.40**	0.11
34	Arad	**0.16**	0.00	0.03	**0.62**	**0.34**	**0.40**	0.12	0.22	**0.43**	**0.37**	**0.28**	**0.25**	0.27
35	Hazerim Kibbuz	**−0.24**	**−0.59**	**−0.41**	0.09	−0.07	**−0.24**	−0.08	−0.34	**−0.20**	−0.14	**0.29**	**0.24**	−0.14
36	Beer Sheva	−0.07	−0.19	**−0.33**	**0.28**	**−0.14**	**−0.23**	**−0.29**	−0.33	**−0.17**	**−0.34**	**−0.23**	0.00	−0.17
37	Sedom Pans	**−0.22**	**−0.19**	**−0.40**	0.00	**−0.19**	−0.06	**−0.16**	−0.16	**−0.09**	−0.16	**−0.12**	**−0.34**	−0.17
38	Sede Boqer	**−0.50**	**−0.56**	**−0.62**	−0.03	−0.53	**−0.34**	**−0.22**	−0.37	**−0.30**	**−0.84**	**−0.34**	**−0.43**	−0.42
39	Avedat	**−0.37**	**−0.31**	**−0.31**	−0.03	−0.16	**−0.19**	**−0.28**	−0.31	**−0.31**	**−0.47**	**−0.28**	−0.22	−0.27
40	Rekhes Ramon	−0.02	−0.12	−0.09	**0.37**	**0.16**	**0.22**	**0.16**	0.00	0.00	−0.03	0.09	0.08	0.07
	Average	−0.12	−0.31	−0.25	0.32	−0.05	−0.01	−0.02	−0.04	0.27	−0.15	−0.27	−0.12	**−0.06**

season, starting from April through October. All stations considered, the median values of the positive trends are 0.21 °C/decade for Tmax and 0.26 °C/decade for Tmin. For the stations exhibiting statistically significant trends only during the warm season, the corresponding median values of the positive trends are 0.32 °C/decade for Tmax and 0.34 °C/decade for Tmin, respectively.

These generally opposing seasonal trend patterns, observed at the 40 stations, are in agreement, with the exception of January, with the long-term trend tendencies of the 500–1000 hPa geopotential thickness patterns, as observed at the Bet Dagan (Mediterranean coastal plain of Israel, station 21, Fig. 1), radiosonde station (see Fig. 3). Since the thickness trends represent the low tropospheric temperature trends, they should not be expected to be identical to the surface trends. However, the more surprising result is that the thickness trends – positive in summer and negative in winter (except January) – are similar to the surface temperature trends. This requires additional study of upper level temperature trends which are unfortunately rather vigor. In analyzing the seasonal trend shown in Fig. 2, a rather complex pattern can be observed. Considerable deviations from the above mentioned prevailing pattern – the cooling tendency during the cold season, and the warming tendency during the warm season – are evident. Some stations show opposite trends to the prevailing one at a given season (and some are not statistically significant (Tab. 1a, 1b)). Some interesting features of the trend patterns are worth nothing and will be discussed in the following.

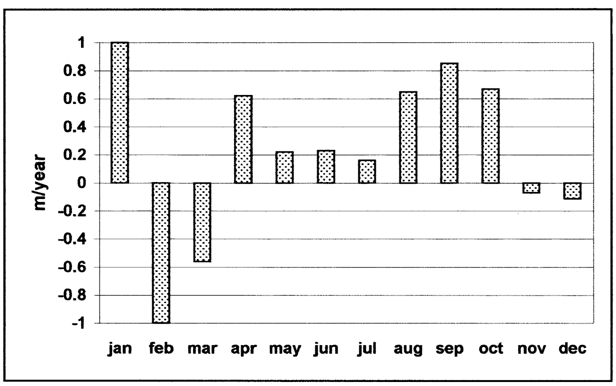


Fig. 3. Geopotential thickness trends of 500–1000 hPa at Bet-Dagan radiosonde station for 1964–1994. Slopes greater than 0.5 m/year are statistically significant

3.1.1 Maximum Temperature Trend Pattern

The Tmax trends of a negative tendency are most coherent during the cool season, especially during January, February and March. The spatial coherency of this tendency is well seen in Fig. 4a, showing the spatial distribution of the maximum temperature trend during the cool season. The cool season here includes 5 months compared to 7 months for the rest warm season of the year (Fig. 2).

A sharp transition from a negative trend in Tmax, practically at all stations during March to a positive tendency in April, is well pronounced (Fig. 2a).

Rather conflicting tendencies, with least statistically significant trends, occur during the warm season, mainly during May and June. The warming tendency becomes more coherent

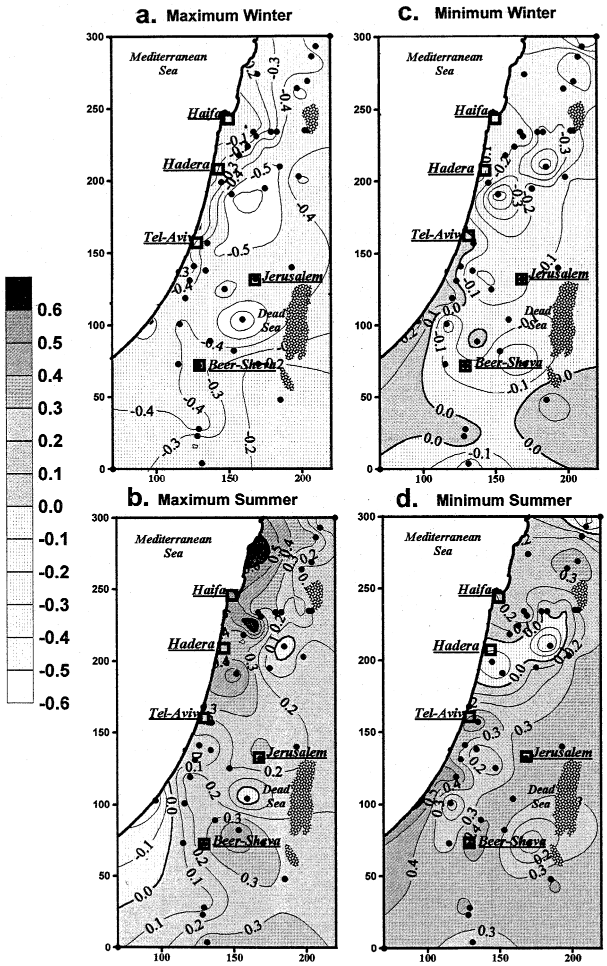


Fig. 4. Spatial distribution of maximum and minimum temperature trends for the cool (November to March), and warm seasons (April to October), 1964–1994. Values are in °C/decade. Maximum temperature for the cool season and warm seasons (a,b), and minimum temperature for the cool and warm season (c,d), respectively

during the remaining months of the warm season, from July through October. Because of the conflicting tendencies the average annual change of maximum temperature is only −0.03 °C/decade (see Table 1a).

The spatial distribution of the Tmax trend pattern during the warm season (see Fig. 4b) shows a negative tendency at the southern coastal plain of the Eastern Mediterranean, conflicting with the general warming trend during this season. The opposite cooling trend, in this region is most probably due to the extreme changes in land use which have taken place in this region during the last decades, development of agriculture under intensive irrigation, with a subsequent decrease in Bowen's ratio (decreasing sensible heat flux with increasing latent heat flux from the surface). These microclimatic and/or mesoscale effect might have offset the general warming tendency during the warm season. This (decreasing trend) area is also co-located with the region where maximum rainfall increases were analyzed by Ben-Gai et al. (1993, 1994, 1998b), particularly in October.

The transition from the positive trend tendency in Tmax in October to the negative tendency in November (Fig. 2a), though less pronounced as compared to the transition from March to April, is also worth nothing.

3.1.2 Minimum Temperature Trend Pattern

The general pattern of the minimum temperature trend is similar to the maximum temperature trend, with a cooling tendency during the cool season, and a warming tendency during the warm season (see Fig. 2). The deviations from the above mentioned general pattern are, however, more strongly pronounced.

The onset of the positive tendency in Tmin during April, at the beginning of the warm season, as opposed to the negative tendency during March, the end of the cold season, is still clearly evident in Tmax, though not as strongly pronounced as in case with Tmax trend pattern.

It should be noted that there is a more coherent behavior of the Tmin positive trend pattern during the warm season, from April through October, as compared to the trend pattern of Tmax during the same season. From November through March the coherence of Tmin trend pattern is less than for Tmax.

Because of the conflicting tendencies, the average annual change of minimum temperature is only 0.05 °C/decade (Tab. 1b). The spatial distribution of Tmin trend pattern also reveals some important features indicative of some microscale and mesoscale effects which may offset or even reverse the overall tendency. During the cool season (Fig. 4c) the general decreasing trend of Tmin is offset in the Southern and the Central coastal plain. The most probable cause for this offset might be the change in land use, i.e. extended urbanization, agricultural activities and aforestation that led to drastic changes in surface properties and increase in surface

Table 2. *Differences between Critical Values of 0.1, 0.5 and 0.9 in °C During 1980–1994 with Respect to 1964–1979, for Tmax and Tmin in February and August*

	Station	Max. 0.1 Feb	Max. 0.1 Aug	Max. 0.5 Feb	Max. 0.5 Aug	Max. 0.9 Feb	Max. 0.9 Aug	Max. 0.1 Feb	Max. 0.1 Aug	Max. 0.5 Feb	Max. 0.5 Aug	Max. 0.9 Feb	Max. 0.9 Aug
1	Dafna	−1.5	−0.1	−1.6	0	−1.7	0.1	−1	−0.1	−0.8	0	−0.6	0.1
2	Kefar Blum	−1.7	0.5	−1.7	0.7	−1.7	0.9	0	0.4	−0.3	0.7	−0.6	1
3	Elon	−1.1	1	−1.5	0.9	−1.9	0.8	−1	0.4	−1.2	0.6	−1.4	0.8
4	Ayyelet Ha Shahar	−2	0.2	−1.7	0.5	−1.4	0.8	−0.4	0.7	−0.5	1	−0.6	1.3
5	Nahariyya	−1.8	−0.1	−1.8	0	−1.8	0.1	−2.1	−0.8	−1.3	−0.4	−0.5	0
6	Har Kenaan	−1.8	0.5	−1.7	0.3	−1.6	0.1	−1	0.5	−1	0.5	−1	0.5
7	Kinneret	−1.3	1	−1.4	1.1	−1.5	1.2	−0.6	−0.4	−0.8	0.4	−1	1.2
8	Deganya Alef	−2	0.1	−1.7	0.2	−1.4	0.3	−1	0.1	−0.8	0.7	−0.6	1.3
9	Newe Yaar	−0.9	0.7	−1.1	0.7	−1.3	0.7	−0.8	0	−0.9	0.3	−1	0.6
10	Tavor Agr. School	−1	0.8	−1.2	0.7	−1.4	0.6	−0.6	0.4	−0.3	−0.8	0	1.2
11	Nazareth Upper Town	−1.7	−0.3	−2.1	0.1	−2.5	0.5	−0.7	0.4	−1.1	−0.5	−1.5	0.6
12	Ramat Dawid	−1.4	0.1	−1.3	0.2	−1.2	0.3	−0.1	1.1	0	1.1	0.1	1.1
13	Mishmar Ha Emeq	−0.8	1.3	−0.9	1.3	−1	1.3	0	0.3	−0.2	0.5	−0.4	0.7
14	Even Yizhaq	−1.3	0.7	−1.4	0.6	−1.5	0.5	−0.7	0.1	−0.7	0.4	−0.7	0.7
15	Biet Qad	−0.9	0.1	−1.6	0	−2.3	−0.1	0.1	−0.1	−0.3	0.1	−0.7	0.3
16	Tirat Zevi	−1.5	0.3	−1.4	0.3	−1.3	0.3	−0.5	0.4	−0.3	0.7	−0.1	1
17	Ein Ha Horesh	−1.2	1	−1.5	0.9	−1.8	0.8	−0.8	0.3	−0.8	0.2	−0.8	0.1
18	Meithalun	−1.9	−0.1	−1.8	0.3	−1.7	0.7	−0.7	0.3	−0.8	0.4	−0.9	0.5
19	Tulkarm	−1.7	1.2	−1.9	1.2	−2.1	1.2	−1.3	0.1	−1.3	0.4	−1.3	0.7
20	Tel Aviv Sede-Dov	−0.8	0.3	−1.1	0.5	−1.4	0.7	−0.4	0.4	−0.7	0.6	−1	0.8
21	Bet Dagan	−2	−0.3	−2	−0.1	−2	0.1	0.1	1.5	0	1.3	−0.1	1.1
22	Yavne Kvuza	−1	0.1	−1.3	0	−1.6	−0.1	−0.3	0.7	−0.4	0.8	−0.5	0.9
23	Jericho	−1.9	0.4	−1.8	0.4	−1.7	0.4	−0.6	0.4	−0.6	0.7	−0.6	1
24	Mazkeret Batya	−1.5	0.1	−1.6	0	−1.7	−0.1	−0.4	0.2	−0.5	0.4	−0.6	0.6
25	Jerusalem	−1.8	0.6	−1.8	0.7	−1.8	0.8	−1.1	0.2	−1	0.5	−0.9	0.8
26	Hazor Ashdod	−1.3	0.6	−1.5	0.3	−1.7	0	−0.1	0.1	−0.1	0.6	−0.1	1.1
27	Beit Jimal	−2.1	0.5	−1.9	0.4	−1.7	0.3	−1	0.6	−1.1	0.4	−1.2	0.2
28	Negba	−1.7	0.3	−1.7	0	−1.7	−0.3	0.6	1.5	0.2	1.2	−0.2	0.9
29	Hebron	−2	0	−2.1	0	−2.2	0	−0.7	0.8	−0.9	0.8	−1.1	0.8
30	Gaza	−0.9	0	−1.5	−0.3	−2.1	−0.6	0.2	1.3	−0.1	1.2	−0.4	1.1
31	Dorot	−1.7	0.6	−1.7	0.4	−1.7	0.2	−0.4	0.3	−0.7	0.3	−1	0.3
32	Lahav	−1.6	0.8	−1.8	0.6	−2	0.4	0.1	1	−0.2	0.9	−0.5	0.8
33	Yattir	−1.1	1	−1.5	1.4	−1.9	1.8	−0.9	−0.3	−1.3	0.1	−1.7	0.5
34	Arad	−1.6	0.6	−1.8	0.3	−2	0	−0.8	0.3	−0.8	0.6	−0.8	0.9
35	Hazerim Kibbuz	−1.7	0.7	−1.4	0.7	−1.1	0.7	−1.5	0.3	−1.3	0.1	−1.1	−0.1
36	Beer Sheva	−1.5	0.6	−1.5	0.4	−1.5	0.2	−0.5	0.9	−0.7	1	−0.9	1.1
37	Sedom Pans	−0.7	0.6	−0.5	0.6	−0.3	0.6	0.1	0.8	−0.2	0.8	−0.5	0.8
38	Sede Boqer	−1.6	0.4	−1.6	0.2	−1.6	0	−0.2	0.8	−0.3	0.8	−0.4	0.8
39	Avedat	−0.9	0.3	−1.2	0.2	−1.5	0.1	−0.4	0.6	−0.4	0.8	−0.4	1
40	Rekhes Ramon	−1.4	0.7	−1.7	0.6	−2	0.5	−0.9	0.4	−1.3	0.6	−1.7	0.8

radiation balance. Therefore, the night minimum temperature tends to increase, most probably offsetting the general decreasing tendency during the cool season.

The most striking example of such a biasing effect is the trend pattern of Tmin at the Gaza station. A positive, statistically significant trend in Tmin prevails in Gaza all throughout the year in both seasons. An illustration of this outstanding warming trend in the cool season, for December, is shown in Fig. 5. It should be mentioned that the population of the Gaza strip has increased immensely during the last decades.

Figure 4d exhibits coherent distribution of increase in minimum temperature in summer at most of the stations, except the Hadera area that is stretched downstream from the coast towards the Northeast. The decreased trend in this area, opposed to the general increase in minimum temperature, might be related to the considerable heat release by the large Hadera power plant complex which has been operating since the

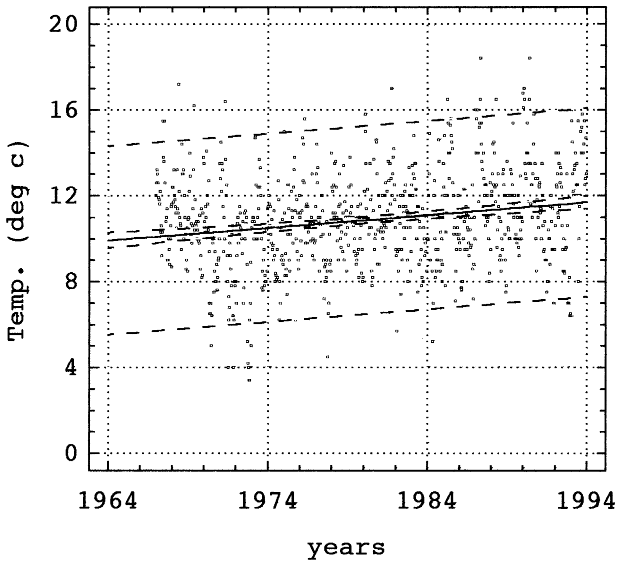


Fig. 5. Scatter plot of Tmin in Gaza for December days, 1967–1994. The warming trend is indicated by the full line

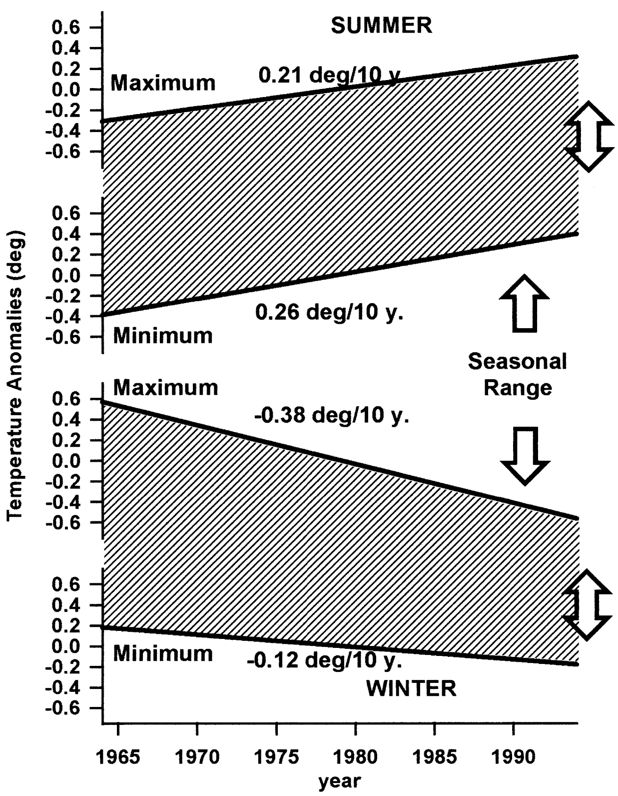


Fig. 6. Fitted serial regression for the median of Tmax and Tmin, for the cool and warm seasons 1964–1994

early 1980's (Tokar et. al., 1993). Heating the upper mixing depth could have acted to diminish the night- time clouds, and thus enabling the more efficient nocturnal release of surface heat to the atmosphere.

3.1.3 Trend Patterns of the Diurnal and Seasonal Ranges

The diurnal range, the difference between the daytime maximum temperature and the nighttime minimum temperature, as well as the interseasonal range, which is the difference between the maximum and minimum temperatures between the warm and the cold season, are important climatic characteristics. Climate change may involve either moderation or a tendency towards extremity of the diurnal range and/or the inter-seasonal range. It is thus important to examine the trend patterns of the interseasonal and diurnal ranges.

The overall warming tendency during the warm season, with the cooling tendency during the cool season, will obviously lead to an appreciable increase of the interseasonal range. In view of the overall positive tendency in both Tmax and Tmin during the warm season, and the respective negative trend during the cool season, the diurnal range pattern depends primarily on the differential nature of the Tmax and Tmin trend patterns for both seasons. Such differences might have been determined by considerable changes in land uses which have taken place during the last decades due to urbanization, aforestation and agricultural activities under intensive irrigation. Also, some deviations from the general patterns at stations in the central mountain regions are also worth nothing.

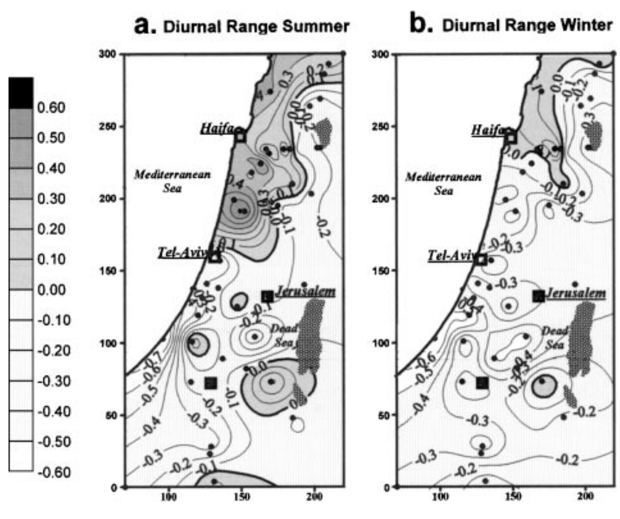


Fig. 7. Spatial distribution of the diurnal range trend patterns for the (a) warm and (b) cool seasons, 1964–1994. Values are in C°/decade

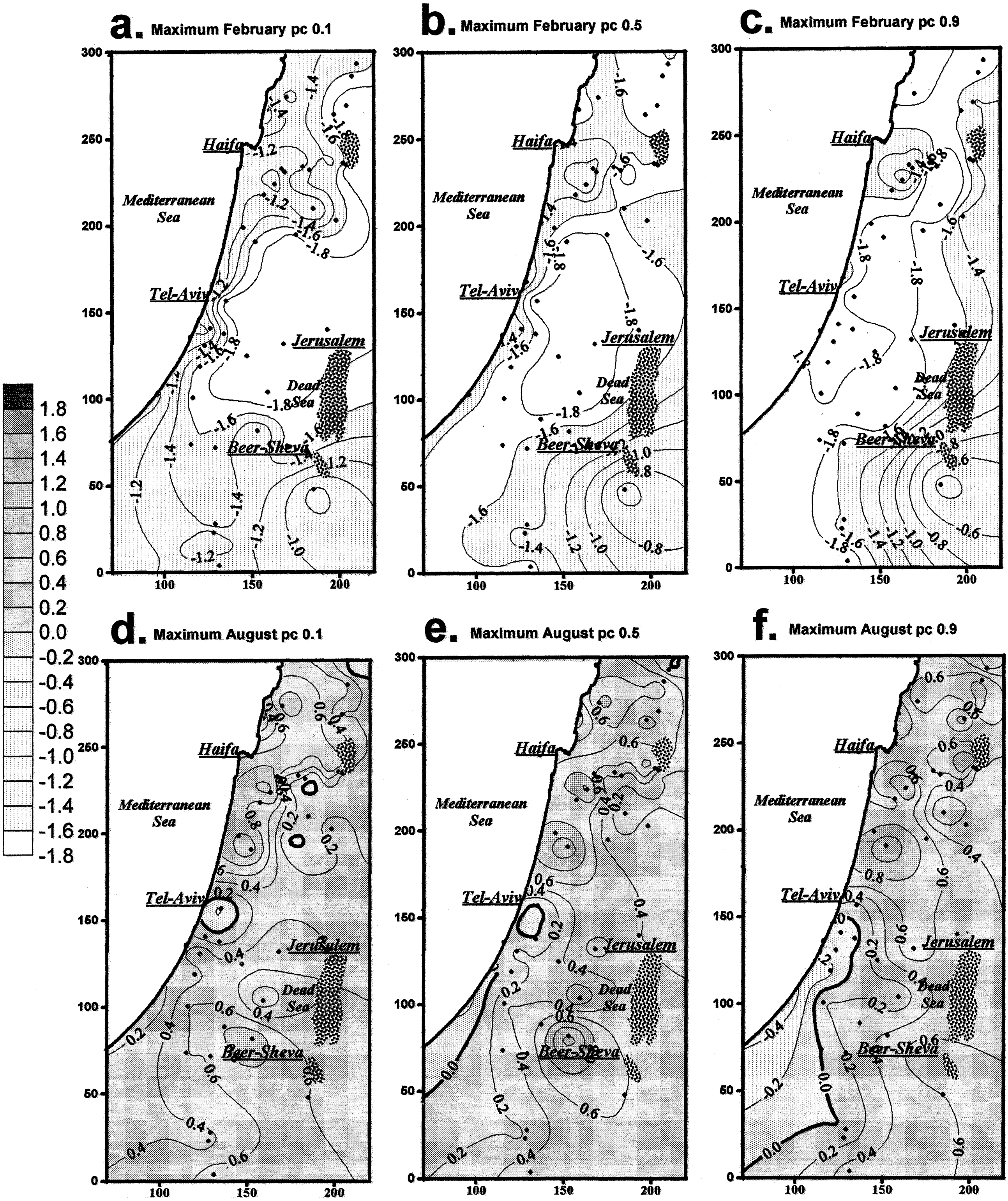


Fig. 8. Spatial distribution of the differences between the median and the critical percentiles (in °C) during 1980–1994 with respect to 1965–1979. a-f Tmax differences for the percentiles of 0.1, 0.5 and 0.9 for February (a–c) and August (d–f). g–l Tmin differences for the percentiles 0.1, 0.5 and 0.9 for February (g–i) and August (j–l)

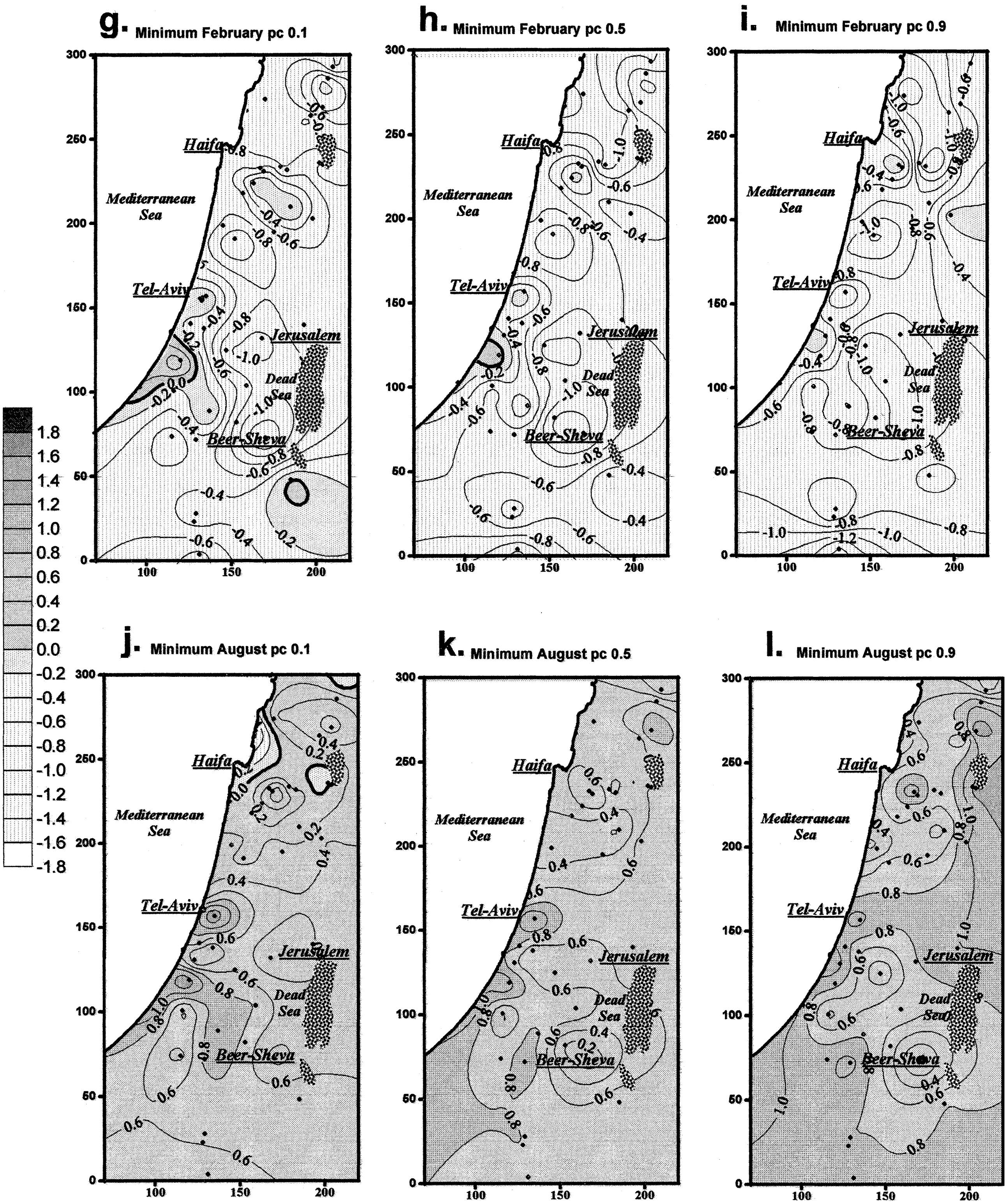


Fig. 8 (*continued*)

The fitted serial regression lines for Tmax and Tmin, for the cool and warm seasons, respectively, are plotted in Fig. 6 thus revealing clearly the decreasing trend pattern of the diurnal range by $-0.05\,°C$/decade, and $-0.26\,°C$/decade for summer and winter, respectively, as well as the appreciable increase of the interseasonal range by $0.49\,°C$/decade (Table 1c).

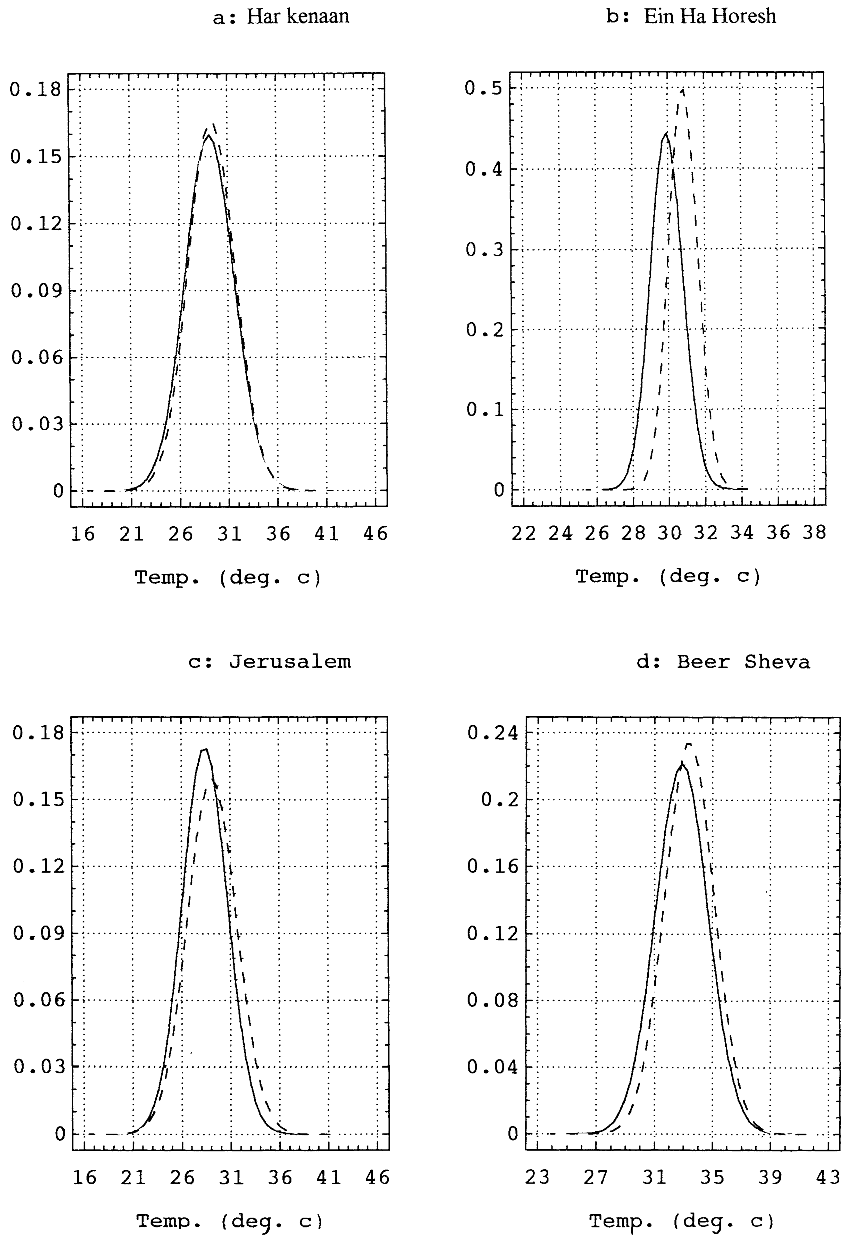


Fig. 9. Frequency distribution of the two sub-periods for maximum and minimum temperature at (a,e) Har Kenaan, (b,f) Ein Ha Horesh, (c,g) Jerusalem, and (d,h) Beer-Sheva, see Fig. 1, Stations 6, 36, 25 and 17, respectively. First period is indicated by the full line and the second period by the dashed line. a–d Maximum temperature, August e–h Minimum temperature, February

The spatial distribution of the diurnal range trend pattern for both, the cool and warm seasons, is plotted in Fig. 7a and 7b, respectively. As one can see, the diurnal range during the cool season (Fig. 7a) shows a strongly pronounced decreasing trend in the southern coastal plain, with an increasing trend at some stations in the North-west. A similar spatial pattern can also be seen in the warm season (Fig. 7b) with a considerable southward decreasing trend and an opposite pronounced increasing trend northward. The main difference between the cool and warm seasons is evident only in the North. It is of interest to note that the southward decreasing trend of the temperature diurnal range, seems to be in agreement with previous studies of rainfall distribution patterns (Ben-Gai et al., 1993, 1994, 1998b) showing a decrease in spottiness and interannual variability, both indicative of a retreat of aridity.

3.2 Changes in Frequency Distribution Patterns of Tmax and Tmin

As was shown in some recent studies (e.g., Mearns et al., 1984; Katz, 1992) even a small

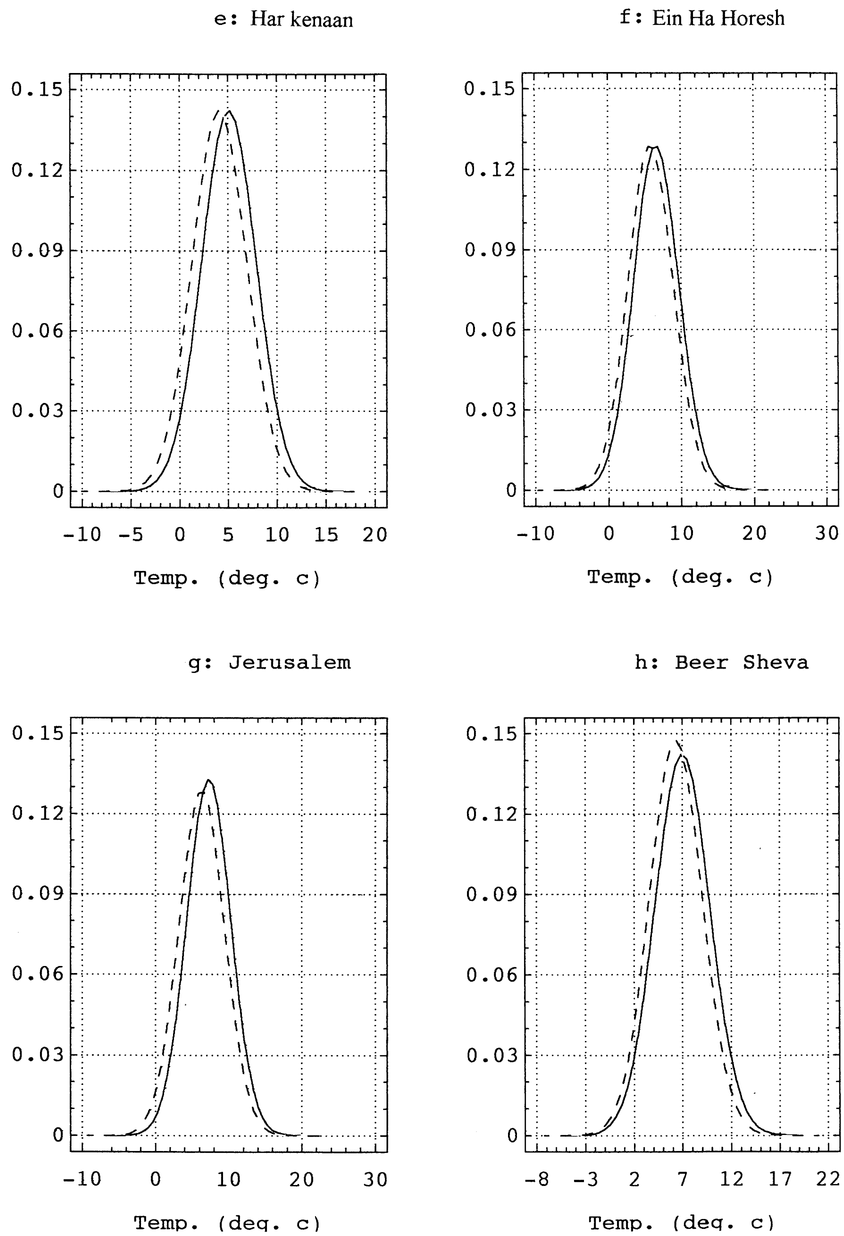


Fig. 9 (*continued*)

shift in the location of a frequency density distribution of a climatic variable (which is equivalent to the mean in a normal distribution) might result in relatively large changes in extreme events probability. The frequency of extreme events may also reflect changes in variability rather than changes in mean values (Katz and Brown, 1992).

It was, therefore, of interest to examine what changes have occurred in the frequency distribution patterns of Tmax and Tmin in Israel at the 40 stations selected for this study, especially with regard to extreme events expressed by the critical values of the frequency distributions.

The total period of study, 1964–1994, was divided into two sub-periods: 1964–1979 and 1980–1994. A normal frequency distribution was fitted to the empirical distributions of Tmax and Tmin for each sub-period at all stations (Brown and Katz, 1995). August, representing the warm season, and February, representing the cool season, were selected for this examination (Table 2). The critical values of the distributions were chosen to be represented by the 10^{th} (0.1) and 90^{th} (0.9) percentiles, respectively (Palumbo and Mazzarella, 1984). The spatial distributions of the differences between the critical values and the median (in °C), during the second sub-period with respect to the first one, for Tmax and Tmin in February and August, are plotted in Fig. 8a. The February critical values of Tmax (representing the cool season) exhibit a considerable decrease during the second sub-period, as low as $-2.0\,°C$ for the 10^{th} percentile. The critical values for August, representing the warm season, exhibit an opposite pattern, though less pronounced, shifting towards higher temperature values (see Fig. 8).

The changes in frequency distribution patterns during the second sub-period versus the first one, at some selected stations representing various climatic regions in Israel, are plotted in Fig. 9. During the second sub-period, over most of the country, the mean of Tmax and Tmin shifts towards lower temperatures in February (Fig. 9a–9d), while in August, the mean shifts towards higher temperature values (Fig. 9e–9h). For instance, in Jerusalem, the most frequent maximum temperature in the early period (1965–1979) was 28.4 °C (Fig. 9c, bold line) and has changed to 29.1 °C in the second period (1980–1994) (Fig. 9c, dashed). In contrast, the corresponding numbers for February minimum temperatures were 7.3 °C and 6.3 °C, respectively. These changes in the location, however, are not as persistent in all stations as during the cool season.

4. Summary and Conclusions

The analysis of the trend patterns of maximum and minimum surface temperatures observed at 40 stations in Israel, during a period of 31 years during the second half of the 20th century (1964–1994), reveal an overall well pronounced seasonal pattern, with a cooling tendency of both Tmax and Tmin during the cool season, and a warming tendency during the warm season. For annual means, however, there seems to be almost no temporal trend in minimum and maximum temperatures since the changes in winter and summer are of the opposite tendency.

A clearly decreasing trend in the diurnal range is revealed by $-0.05\,°C$/decade and $-0.26\,°C$/decade for the summer and winter, respectively, as well as an appreciable increase of the interseasonal range.

The nature of the observed trend patterns, with a rather abrupt change from a negative tendency at the end of the cool season, i.e. March, to a positive one at the beginnig of the warm season, i.e. April, seem to imply that these changes were most probably imposed by some external factors. Possible teleconnections with the observed surface temperature anomalies will be examined in a forthcoming paper.

The general trend patterns exhibit, however, appreciable deviations, which seem to reflect some microclimatic and mesoscale effects, most probably caused by drastic changes in land use, i.e. by the development of agriculture under intensive irrigation, extended urbanization and aforestation which took place, in Israel during the last decades. These effects seem to be most strongly pronounced in the Southern coastal plain and in the semi-arid region of the North-western part of the Negev desert.

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