Wind Variability—An Indicator for a Mesoclimatic Change in Israel

PINHAS ALPERT

Department of Geophysics and Planetary Sciences, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, Israel

MOSHE MANDEL

Department of Climatological Documentation, Israel Meteorological Service, Bet-Dagan, Israel

(Manuscript received 15 April 1985, in final form 20 April 1986)

ABSTRACT

It is shown that the normalized diurnal and interdiurnal surface wind variabilities have a clear decreasing trend in central–southern Israel for the last three decades. This trend is found in the surface data of the independent time series of three meteorological stations in this area. It is suggested that this change indicates a mesoscale modification of climate which is induced by the agricultural development and settlement of the central to southern part of Israel in the recent decades. The decreasing trend becomes particularly strong during the 1960s and this is correlated to the enhanced irrigational effects due to the starting-up of the National Water System in 1964. It is proposed that the region may have gone through a similar but reversed mechanism to that of the desertification process (reversed desertification!?) that was largely investigated in association with the Sahel zone drought.

1. Introduction

Most climatic research deals with large-scale changes of the meteorological parameters like rainfall, temperature, pressure, etc., but fewer climatic studies have dealt with the climatic change over short periods as modified by man, e.g., see Changnon (1973).

Climate modification by man was in general studied either through the effect on large-scale conditions as, for example, the increase of CO_2 concentrations and the associated long-range climatic changes or through much smaller scale effects such as those produced by urbanization. In this study we will focus rather on the mesoscale modification of climate which is induced by the agricultural development and settlement of the central to southern part of Israel in the recent decades.

The desertification process was investigated by some researchers particularly in association with the drought at the Sahel Zone, e.g., see Otterman (1974), Charney (1975), Charney et al. (1975) and Idso (1980). The basic hypothesis was that overgrazing of the land led to an increased albedo, which in turn led to a reduction in convective activity and reduced rainfall. Israel might be an example of just the opposite process which we will refer to as the reversed-desertification mechanism. Here it will be suggested that the diurnal and the interdiurnal wind variabilities might serve as efficient diagnostic parameters for climatic studies, see Alpert and Eppel (1985). The decreasing trend of the wind variability in central Israel during the period 1951–81 will be associated with the enhanced agricultural and general development that took place in the same region. In the last section the manmade changes of some physical parameters like moisture availability, roughness and albedo will be discussed as possible causes for the climate modification in the region.

2. Diurnal and interdiurnal wind variability

Alpert and Eppel (1985) calculated the diurnal and interdiurnal surface wind variabilities in terms of the "relative gustiness"—$\sigma_v/\bar{v}$ where σ_v and $\bar{v}$ are the standard deviation and average wind intensity respectively. Over short time scales this is known as the turbulence intensity and for the longitudinal component of the wind it is strongly dependent upon the terrain as shown for example by Lumley and Panofsky (1964, p. 154). Here we will refer to longer time intervals and define the normalized diurnal wind variability I_B as

$$I_B = [\sum_{i=1}^{24} (u_{ij} - u_j)^2]^{1/2}/(24^{1/2}u_j), \qquad (1)$$

where: u_{ij} is the wind intensity at hour i and day j and $u_j = (\sum_{i=1}^{24} u_{ij})/24$ is the average diurnal wind intensity for the jth day. The average value of I_B over N days is given by

$$\bar{I}_B = \frac{1}{N}\sum_{j=1}^{N} I_B. \qquad (2)$$

Similarly, the normalized interdiurnal wind variability I_A is

$$I_A = [\sum_{j=1}^{N} (u_j - \bar{u})^2]^{1/2}/(N^{1/2}\bar{u}) \qquad (3)$$

where

$$\bar{u} = (\sum_{j=1}^{N} u_j)/N.$$

The total normalized wind variability I_C is defined by

$$I_C = [\sum_{j=1}^{N}\sum_{i=1}^{24} (u_{ij} - \bar{u})^2]^{1/2}/[(24N)^{1/2}\cdot\bar{u}]. \qquad (4)$$

In general, $I_c > \bar{I}_B$, but if the interdiurnal variability becomes very small I_c may slightly drop below $\bar{I}_B$. This can be easily shown for the limiting case of $I_A = 0$ where $I_c < \bar{I}_B$ (for $N > 1$). In the following calculation N was chosen to be the number of observational days during the month which was in general 31. The ratio of $\bar{I}_B$ to I_A denoted by α was suggested by Alpert and Eppel (1985) as a useful index for mesoscale activity in the following manner: In regions where $\alpha > 1$ (i.e., $\bar{I}_B > I_A$) the diurnal variability $\bar{I}_B$ which is primarily caused by differential heating forces and topographic effects is larger than the large-scale (synoptic) contribution to the wind variability as expressed by I_A and vice versa. In fact, they have shown that in July nearly all stations in Israel gain relatively high mesoscale indices ($\alpha > 1$), whereas in January nearly all α-values are smaller than one. This was not unexpected as the Israeli summer is characterized by the semipermanent synoptic upper-level subtropical ridge and a vigorous diabatic heating while in winter the midlatitude migrating cyclones dominate the weather. In this study we are concerned with the changes of the diurnal ($\bar{I}_B$) and interdiurnal (I_A) wind variabilities during the last three decades. In other words, we are interested in possible climatic change of the mesoscale as reflected by the diurnal and interdiurnal wind variability.

3. Surface-wind variability at Lod Airport

Figure 1 presents the time series of I_A and $\bar{I}_B$ at Lod airport (32°00′N, 34°54′E) for July and January for the period 1950–80. In each case there are three curves which represent 5-year running means (dashed), 3-year running means (dashed–dotted) and the yearly nonaveraged values (dotted). The most prominent feature of all the curves is a decreasing trend. This trend is particularly evident for $\bar{I}_B$–July and I_A–January. For example, the five-year running mean of $\bar{I}_B$–July decreases from 0.58 in 1953 to 0.45 in 1979 (a decrease of 22 percent). Nearly all I_A and $\bar{I}_B$ values are in the

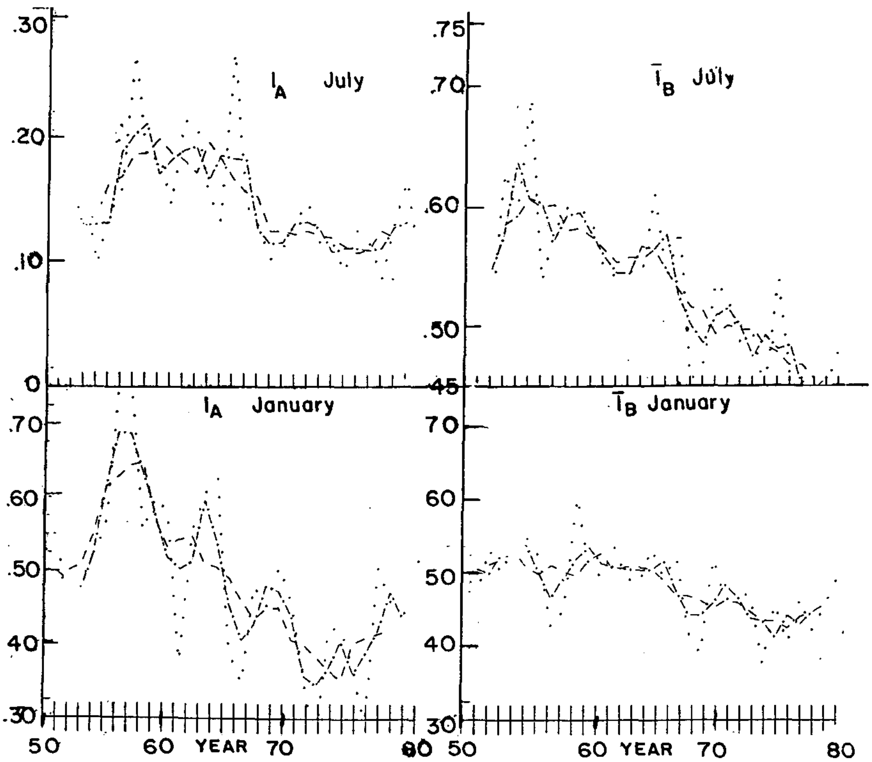

FIG. 1. The time series of I_A and $\bar{I}_B$ at Lod airport (32°00′N, 34°54′E) for July and January for the period 1950–80. In each case there are three curves which represent 5-year running mean (dashed), 3-year running mean (dashed-dotted), and the yearly nonaveraged values (dotted). Each curve represents an interpolated line between the yearly data points.

range of 0.40–0.60, except the I_A–July values which are as small as 0.15 and lower. This reflects the small contribution of the synoptic scale changes to the summer wind variability. Clearly, the summer index of mesoscale activity α ($=\bar{I}_B/I_A$, not shown here) is a good bit larger than unity and generally in the range of 2.5 to 4. But in January the α index oscillates near one, which indicates the comparable contributions of both the mesoscale and the large-scale to the wind variability. The oscillation around the general decreasing trend in Fig. 1 represents the inter-annual variations which are associated with the large-scale fluctuation, as found in other climatological parameters as well.

In order to illustrate the magnitudinal variation of $\bar{I}_B$ and I_A as related to the total wind variability I_C, Figs. (2a) and (2b) depict their yearly nonaveraged time series for July and January. The outstanding feature during summer is the nearly equal values of $\bar{I}_B$ and I_C reflecting the near absolute dominance of the mesoscale contribution to the total wind variability. Notice that I_C may even become slightly smaller than $\bar{I}_B$, as mentioned earlier. In contrast, in January the $\bar{I}_B$ and I_A values are comparable. It is important to note that the extreme values of $\bar{I}_B$ and I_A tend to be in the opposite sense. In other words, the years which show maxima for the I_A value, i.e., large-scale dominance, are also associated in general with a minima of the $\bar{I}_B$ value, i.e., small mesoscale activity. For instance the Januaries of 1957, 1964 and 1968 belong to this class of years in which the large-scale is clearly prevailing the mesoscale, whereas the years 1952 and 1972 exhibit just the opposite behavior. The overall decreasing trend is again remarkable in this figure as well.

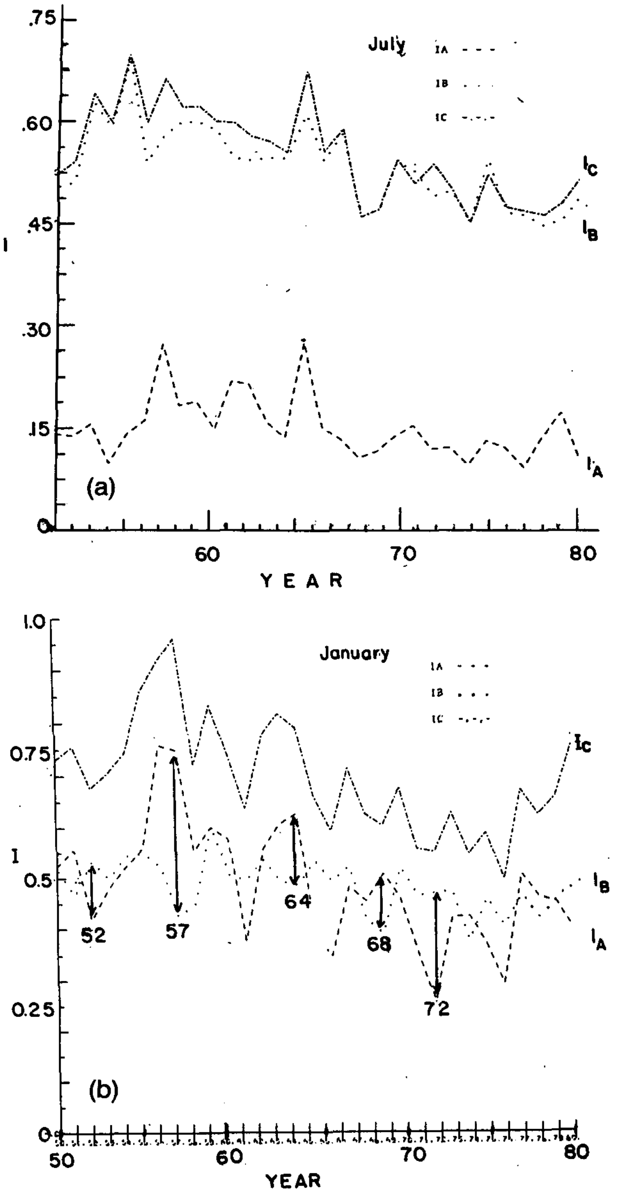

FIG. 2. The yearly nonaveraged time series for I_A (dashed), $\bar{I}_B$ (dotted) and I_C (dashed-dotted) for the (a) month of July and (b) January in the years 1951–80. Arrows in (b) indicate the years in which maximum in $\bar{I}_B$ is associated with minima in I_A and vice versa.

4. Wind variability at Bet-Dagan, Israel—Comparison with Lod and upper air data

One might ask about the aforementioned trend if it is a consequence of a mesoclimatic change only, or a result of other local contributions as, for example, changes of the station's local environment. This question is of particular importance to such a meteorological parameter like the wind intensity, which is highly sensitive to any change in the type of instrument or to its immediate neighborhood. If this trend is really of mesoscale nature (say of horizontal scale of more than 5 to 10 kilometers), then one would expect this trend to show up in a relatively distant location which is still under the same mesoscale influence. The Bet-Dagan IMS (Israel Meteorological Service at 32°00′N, 34°49′E) station, which is located at about 10 kilometers west, northwest to Lod Airport, was chosen as an additional station in order to study the possible mesoclimatic change. The upper air data which are available in Bet-Dagan, allow us to calculate interdiurnal upper-air wind variability and compare it with the respective value at the surface. Figures 3a, b illustrate the 3-year running mean of I_A at Lod and Bet-Dagan over about the last three decades. Noting that for Bet-Dagan the calculation is based upon 1200 GMT data, one may expect that in this method (based upon only one-hour data rather than on the mean diurnal values) higher interdiurnal variabilities will be obtained. However, no changes are expected in regard to trend and interannual oscillations in both procedures of I_A calculation. This is confirmed by Figs. 3a and 3b in which the Bet-Dagan I_A-values exceed those of Lod.

As illustrated by Figs. 3a, b, the decreasing trend of I_A is also noticed in Bet-Dagan. In spite of some in-

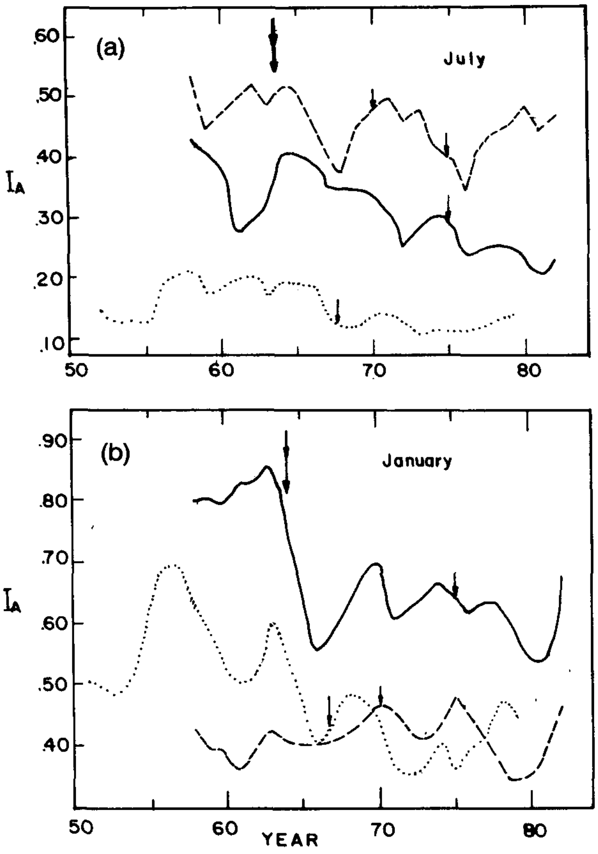

FIG. 3. The 3-year running mean of I_A for (a) July and (b) January at Lod (dotted) and Bet-Dagan (solid) from the 1950s to ~1980. The dashed line is the I_A curve for the wind intensity at 500 mb based upon 1200 GMT data. Small arrows indicate change of wind instrument. Large arrow at 1964 designates the start-up of the National Water System.

strumental changes that occurred in both stations during the period analyzed, the interannual oscillations are similar. But, it should be noticed that this similarity is weaker in summer due to the diminished effect of the large-scale which is represented by I_A. However, this increases our confidence that the aforementioned trend represents a real mesoclimatic change.

One should pay a special attention to the remarkable decrease of I_A around the years 1964–65, and we shall return to this point later.

The curves for the 3-year running mean of the I_A value at 500 mb, which are also given in Fig. 3, do not show the same decreasing trend. The 500 mb I_A on July do show a decreasing trend which may be due to larger-scale climatic variations. For example, Angell and Korshover (1983) indicate a similar decreasing trend in the variation of mean-annual temperatures in the 850–300 mb layer at the north-temperate zone (30°N–60°N) from 1958 to 1976. The same is true for the 850 mb curves (not shown here). These probably reflect the fact that the lower boundary is responsible to the decreasing trend which occurred at the surface wind variability I_A and $\bar{I}_B$.

5. A possible explanation to the mesoclimatic change

Figure 4 shows the water consumption in Israel for the period of 1958–79. The percentages are on the basis of the 1958 value, which is 1032.264×10^6 m^3. Data for this curve were taken from Greenvald (1981). It is evident that 1964 represents a sharp turning point representing the starting-up of the national water system on June of that year. Through this system large amounts of water are transferred from Lake Kinneret, the large drainage basin of the north (600–1000 mm yr^{-1} rain), to the southern dry region of Israel (up to 250–300 mm yr^{-1}). In Fig. 5 a map of the National Water System is shown. The amount of water of about 0.5×10^9 m^3 which irrigates southern Israel primarily during summer is estimated to be equivalent to a summerly rain of 100 to 200 mm yr^{-1}. As a direct result of this irrigation the moisture availability has increased and successful agriculture has been developed. This was accompanied by an albedo decrease and an increase of the roughness parameter. According to the energy balance equation, the increase of the latent heat flux is primarily associated with a reduction of the sensible heat flux. The mechanism is similar to that found in the Oasis effect, e.g., see Oke (1978). The reduction of the sensible heat flux to the atmosphere resulted in smaller differential heating and decreased wind variability as illustrated, for example, by the numerical simulations of Segal et al. (1984) and Zhang and Anthes (1982). Supporting evidence is found in the reduction of the difference between the maximum and the minimum temperatures in the climatological records of some stations in this region like in Beer-Sheva (not yet published). However, these temperature changes as well as other meteorological parameters which are able to support the suggested reversed-desertification are un-

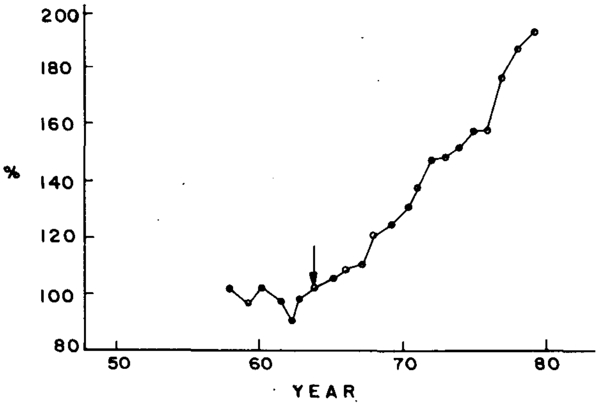

FIG. 4. The total water consumption in Israel for the period of 1958–79. Percentages are on the basis of 1958 value of 1032.264 × 10^6 m^3. Data is from Greenvald (1981).

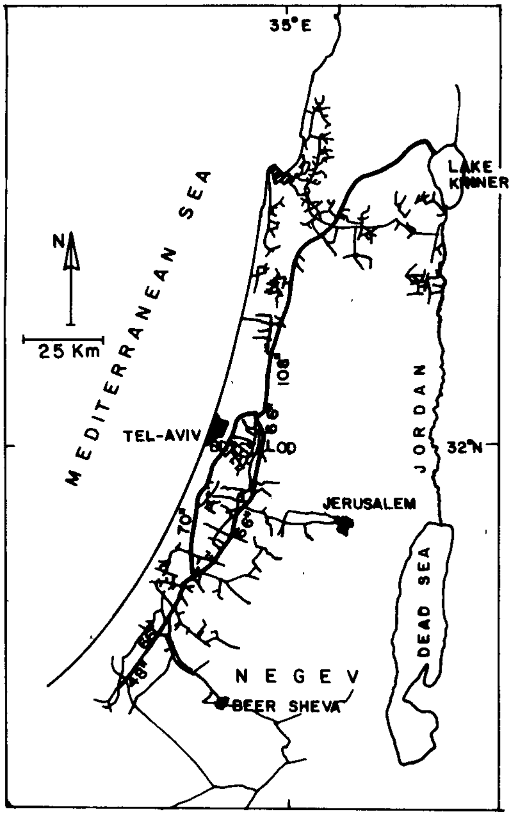

FIG. 5. Map of National Water System. Lod and Bet Dagan (BD) are depicted. Main pipes diameters are indicated in inches.

The decreasing trend of the wind variability for Hafez-Haim—a distinct rural station—which is similar to Lod and Bet-Dagan lends support to our suggestion that the climatic change in central-southern Israel is of a mesoscale nature.

A possible instrumental effect on the wind variability in all three stations may have been due to sensitivity changes in the anemometer. For example, an increase in the number of calm reports because of a different instrument or even due to change in wind-reporting rules may easily lead to an erroneous reduction of the computed wind variability. These may have some contribution to the further decreasing trend in Bet-Dagan following the instrumental change (see Figs. 3a and 3b). But, the existence of the similar decreasing trend in I_A even when based solely upon the 1200 GMT data (1400 LST, a time when wind speeds are in general quite high) renders improbable the possible effect of calm wind reports which are typical at night (see Figs. 7a and 7b).

Another important question relates to the possible expression of such a climatic change through other meteorological parameters. Of particular interest is the effect of irrigation upon the precipitation. The latter fortunately very small. Further discussion of this point is postponed to the next section.

6. Is it really a mesoclimatic change?—Discussion and further results

A mesoclimatic change is expected to be found over a meso-domain. Lod and Bet-Dagan are too close to each other (~10 km) to clearly define a mesoscale area, and in recent years they became closer to the main urban center of Israel, i.e., the town of Tel Aviv and vicinity. Actually, both stations became gradually positioned at the leeside of the growing Tel Aviv metropolitan area. Goldreich and Manes (1979) have shown that the urban effects upon the precipitation patterns may well reach Lod and Bet-Dagan. In order to exclude the urban effect we have examined a third station named Hafez-Haim, which is located at about 30 km south of Tel Aviv (see Fig. 6). Hafez-Haim is clearly free from any major urban development in its vicinity, but extensive agriculture did indeed take place there in recent decades and particularly since the operation of the National Water System.

Figures 7a and 7b present the 3-year average means for I_A at Hafez-Haim in July and January for the period 1955–81. The dashed lines present the I_A values which were derived from a single diurnal point at 1200 GMT.

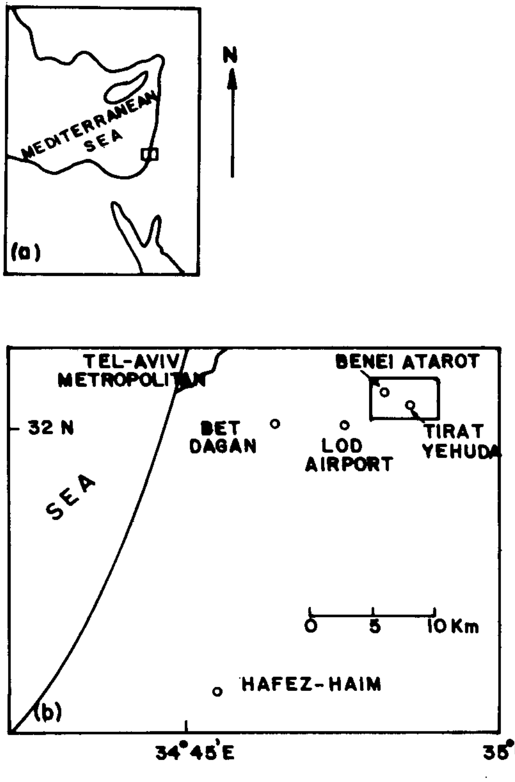

FIG. 6. (a) Schematic map for the Eastern Mediterranean where the "study domain" is designated by the rectangular area in central Israel. (b) The enlarged map of the "study domain" in Fig. 6a. The relevant points are depicted. The rectangular area to the northeast illustrates the approximate frame of the airplane pictures (see Figs. 9a and 9b).

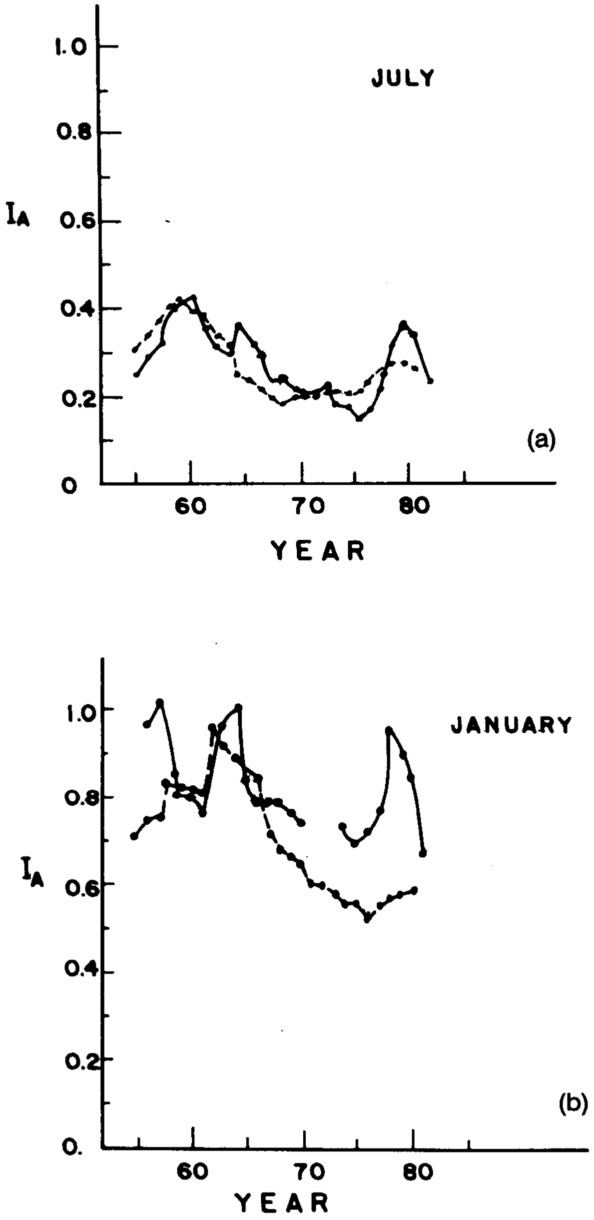

FIG. 7. The 3-year running mean of I_A for (a) July and (b) January at Hafez-Haim from 1955 to 1981. Full curve in (a) is for the line derived according to all available diurnal data while the dashed line is based solely on 1200 GMT wind speeds. The diurnal wind data in (b) for the years 1971–74 were not sufficient, i.e., less than five synoptic reports per day.

effect was well illustrated in the United States by Barnston and Schickendanz (1984). However, the irrigation-induced rainfall is difficult to isolate in Israel due to the coexistence of additional major factors upon precipitation such as urban effects, air pollution and cloud seeding. Also, there are much more yearly wind data than precipitation data which makes it easier to identify a small but a consistent trend over a period of about 30 years.

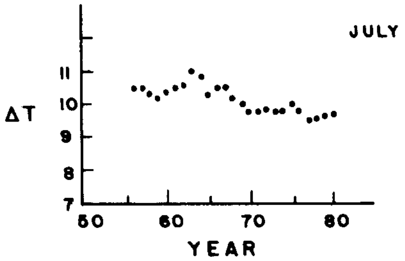

FIG. 8. (a) The monthly averaged surface temperature differences between 1200 and 0000 GMT (1400 and 0200 LST) for July at Hafez-Haim in the period 1956–80.

Another parameter which may be directly influenced by the irrigation is the difference between day and night temperatures. Figures 8a and 8b present the average temperature differences between 1200 GMT and 0000 GMT (1400 LST and 0200 LST, respectively) for July and January in Hafez-Haim during the period 1956–80. It is interesting to notice that as expected, owing to intensive irrigation (e.g., see Holmes, 1970), this value drops steadily. It is particularly noticed in the 1960s summer month of July when extensive irrigation was taking place in the central-southern semiarid region of Israel.

The idea of shelter belts of trees that may have been planted near Lod and Bet-Dagan in order to reduce high wind speeds was also examined. It was found that few shelter belts of trees were indeed planted during the early 1950s on the road at about 3 km east of Lod (road of Lod to Petah Tikva). However, the trees are not on the typical windward side which is to the west. Therefore, we expect their monthly averaged effect to be minor at the aforementioned stations.

Following our critical discussion of the possible different influences upon the decreasing trend of the wind variability, we have performed a time trend analysis. The results are presented in Table 1. In this table we list the regression equation coefficients for I_A, I_B at Lod and for I_A, ΔT at Hafez-Haim (the nonaveraged val-

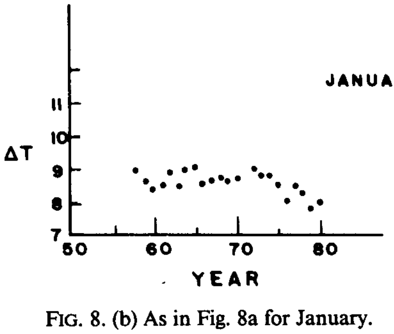

FIG. 8. (b) As in Fig. 8a for January.

TABLE 1. Statistical analysis of the decreasing trend for I_A, I_B at Lod, and for I_A, ΔT at Hafez-Haim. $I_A(12)$ indicates values based solely on the 1200 GMT wind speeds.

Station	Month	Parameter	Mean ± standard deviation	Regression equation Intercept (a_0)	 Slope (a_1)	Correlation coefficient
Hafez-Haim	Jan	$I_A(12)$	0.70 ± 0.20	0.977	−0.010	−0.44**
	Jul	$I_A(12)$	0.27 ± 0.09	0.387	−0.004	−0.41**
	Jan	I_A	0.82 ± 0.18	0.974	−0.005	−0.23*
	Jul	I_A	0.27 ± 0.10	0.391	−0.004	−0.34**
	Jan	ΔT	8.3 ± 1.3	9.9	−0.06	−0.37**
	Jul	ΔT	9.7 ± 0.75	10.9	−0.043	−0.47***
Lod	Jan	I_A	0.49 ± 0.12	0.657	−0.007	−0.53***
	Jul	I_A	0.15 ± 0.04	0.200	−0.002	−0.37**
	Jan	I_B	0.48 ± 0.05	0.557	−0.003	−0.52***
	Jul	I_B	0.53 ± 0.04	0.655	−0.005	−0.68***

* Significant at 7.5%.
** Significant at 5%.
*** Significant at 1%.

ues). As is easily noticed, all the parameters analyzed show a statistically significant decreasing trend. The decreasing trend is particularly strong in the I_B values at Lod. This is not unexpected because, as illustrated by Alpert and Eppel (1985), the normalized diurnal wind variability I_B is a faithful representative for the mesoscale activity induced by the topography.

It seems that the mesoclimatic change indicated by the trend in the wind variability cannot be entirely related to irrigation but rather to the composite effect of irrigation and the major albedo and roughness changes. The latter could be well illustrated by two aerial photographs of the same area northeast of Lod where one was taken in 1944, and the other in 1980 (see Figs. 9a and 9b).

Both photographs were taken of approximately the same region in the Lod vicinity (see Fig. 6). They illustrate the large changes due to both the new settlements and extensive agricultural activity. The new settlements are Benei-Atarot and Tirat-Yehuda in Fig. 9b, whereas in the older photograph they did not exist. There is some additional contribution to the clear albedo difference between the two photographs, due to the fact that the older one was taken in early winter (11 December) while the new one is for early spring (4 April). But this contribution is estimated to be small

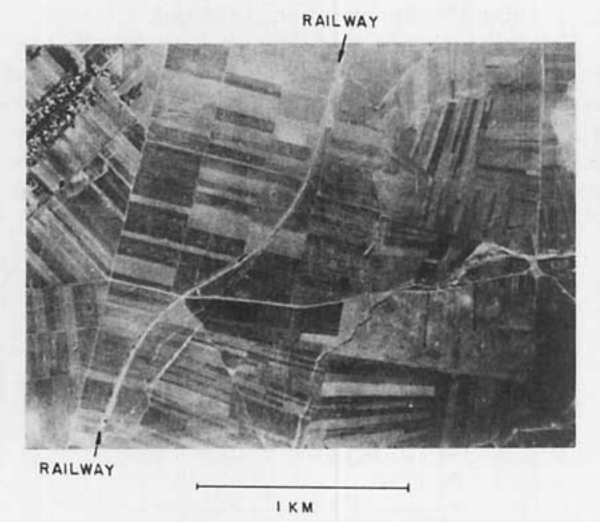

FIG. 9. (a) An airplane picture to the northeast of Lod from the 11 December 1944. The picture domain is shown in Fig. 6. Notice the railway road crossing the picture from southwest to northeast.

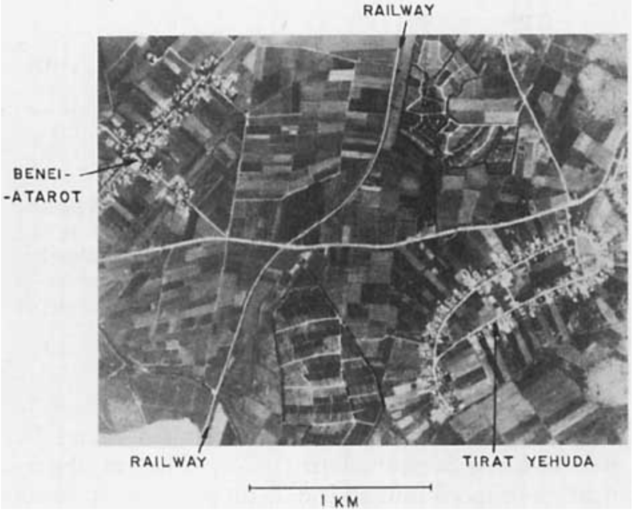

FIG. 9. (b) As in Fig. 9a on 4 April 1980. Notice the two new settlements: Benei-Atarot to the northwest corner and Tirat-Yehuda on the southeastern side. The settlements locations are indicated on Fig. 6.

as compared to the major contribution owing to the extensive agricultural activity that took place in the period between the two photos.

The major effect of albedo changes on local climate and the possibility to enhance precipitation, for example, by asphalt coating was already suggested by Black and Tarmy (1963). Also, the important effect of natural vegetation upon the surface albedo close to the same region, i.e., the semidesert of Sinai, was shown by Otterman and Tucker (1985).

An interesting question in regard with these changes in wind and temperature variabilities is whether the changes are restricted only to the immediate vicinity of the meso-irrigated region both horizontally and vertically. If this is not the case, then these surface changes reflect a more basic change of the regional climate, or what may be referred to as a reversed-desertification process.

Branston and Schickendanz's (1984) clear indications for irrigation-induced rainfall during specific synoptic situations may support the latter, i.e., that a basic change of regional climate is indeed possible. Although the rainfall indications were restricted to marginal synoptic patterns, Budyko (1974, p. 464, in discussing the irrigation effect on the local climate) is of the opinion that in recent years "owing to the rapid growth in population and especially to acceleration of the general development of technology and energy", irrigation may have an important influence on regional climate. This study is the first to indicate that such a mesoscale climatic change may have been indeed taking place in central-southern Israel for the last 30 years.

7. Summary

The dynamics of the mesoscale circulations became of particular interest in recent years for many meteorologists. However, relatively little was done regarding the climate of the mesoscale and especially with regard to manmade mesoclimatic changes. The purpose of the present study is to indicate the persistent decrease in the normalized wind variability (also in the diurnal temperature amplitude) and to suggest its correlation with the agricultural development in the central-southern region of Israel. The basic idea is as follows. The considerable increase of water supply to the south of Israel by the national water system—starting June 1964—led to an increase in the surface moisture followed by major albedo and roughness changes. These may have caused the diurnal and the interdiurnal wind variabilities to drop consistently due to reduced differential heating between land and sea and from the central semiarid to the northern wetter region.

It is suggested that a similar but opposite mechanism to the desertification process that was discussed by many authors may have been taking place in central Israel for the last 30 years. However, to prove the existence of such a mechanism and to substantiate our arguments, there is a need for additional studies which are, in part, underway and, in part, difficult or impossible to properly perform due to the lack of long enough records of reliable data. The following are a few approaches which should be considered in further investigations:

(i) Study more stations in pure agricultural regions both in and out of the irrigated domain in order to estimate the geographic scale of the phenomena.

(ii) Try to isolate the synoptic contribution in the aforementioned trend by analyzing upper air wind data in the region.

(iii) Examine other sensitive meteorological parameters which may have been influenced by the irrigation, such as amount of clouds, wind directions, dewpoint depressions, etc.

(iv) If these changes were induced by irrigation, then one may expect to find month-to-month changes associated with the corresponding changes in irrigation through the year as, for example, shown by Branston and Schickendanz (1984).

(v) Design a boundary layer climate model which will include the relevant parameters in its set of equations and solve them, subject to various changes in the relevant parameters as, for example, surface moisture, albedo and roughness. Such a study will indicate to what extent our suggestion is appropriate and how further inadvertent surface man-induced changes could modify the mesoclimate. Similar studies in the large-scale were already performed as, for example, by Shukla and Mintz (1982).

Acknowledgments. We would like to thank the climate department of the IMS (Israel Meteorological Service) for supplying the meteorological data. Thanks to the Water Commission for the permission to copy the National Water System map, to Ms. Rachel Duani for the nice typing of the manuscript, and to Aharon Dvir for the drafting of the figures. Thanks go also to Ms. A. Eppel who performed the calculations for Lod.

REFERENCES

Alpert, P., and A. Eppel, 1985: A proposed index for mesoscale activity. *J. Climate Appl. Meteor.*, **24**, 472–480.

Angell, J. K., and J. Korshover, 1983: Global temperature variations in the troposphere and stratosphere. *Mon. Wea. Rev.*, **111**, 901–921.

Black, J. F., and B. L. Tarmy, 1963: The use of asphalt coating to increase rainfall. *J. Appl. Meteor.*, **2**, 557–564.

Branston, A. G., and P. T. Schickendanz, 1984: The effect of irrigation on warm season precipitation in the southern great plains. *J. Climate Appl. Meteor.*, **23**, 865–888.

Budyko, M. I., 1974: *Climate and Life.* (English ed. by D. H. Miller) Academic Press, 508 pp.

Changnon, S. A., 1973: Inadvertent weather and precipitation modification by urbanization. *J. Irrigation,* **99,** 27–41.

Charney, J. G., 1975: Dynamics of deserts and drought in the Sahel. *Quart. J. Roy. Meteor. Soc.,* **101,** 193–202.

——, P. H. Stone and W. J. Quirk, 1975: Drought in the Sahara: A biogeophysical feedback mechanism. *Science,* **187,** 434–435.

Goldreich, Y., and A. Manes, 1979: Urban effects on precipitation patterns in the greater Tel Aviv area. *Arch. Meteor. Geophys. Bioklim.,* **B27,** 213–224.

Greenvald, Z., 1981: *Water in Israel 1962–1980.* Ministry of Agriculture, Water Commission, Hakirya, Tel Aviv, 109 pp.

Holmes, R. M., 1970: Mesoscale effects of agriculture and a large prairie lake on the atmospheric boundary layer. *Agronomy J.,* **62,** 546–549.

Idso, S. B., 1980: Surface energy balance and the genesis of deserts. *Arch. Meteor. Geophys. Bioklim.,* **A30,** 253–260.

Lumley, J. L., and H. A. Panofsky, 1964: *The Structure of Atmospheric Turbulence.* Vol. 12, Interscience, 239 pp.

Oke, T. R., 1978: *Boundary Layer Climates.* Methuen, 372 pp.

Otterman, J., 1974: Baring high-albedo soils by overgrazing: A hypothesized desertification mechanism. *Science,* **186,** 531–533.

——, and C. J. Tucker, 1985: Satellite measurements of surface albedo and temperatures in semidesert. *J. Climate Appl. Meteor.,* **24,** 228–235.

Segal, M., R. A. Pielke and Y. Mahrer, 1984: Evaluation of surface sensible heat flux effects on the generation and modification of mesoscale circulations in Nowcasting II. *Proc. Second Int. Symp. on Nowcasting,* Norrköping, IAMAP/WMO, 524 pp.

Shukla, J., and Y. Mintz, 1982: Influence of land-surface evapotranspiration on the Earth's climate. *Science,* **215,** 1498–1501.

Zhang, D., and R. A. Anthes, 1982: A high-resolution model of the planetary boundary layer—sensitivity tests and comparisons with SESAME-79 data. *J. Appl. Meteor.,* **21,** 1594–1609.