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Aircraft Measurements of Surface Albedo in Relation to Climatic Changes in Southern Israel

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With 8 Figures

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Summary

Recent studies imply that significant climatic changes over the central and southern coastal plain in Israel may be due to changes in land usage, which have taken place since the National Water Carrier operation in the early 1960's. Such changes are reflected in the spatial distribution of the surface albedo pattern, obviously resulting in changes in the surface radiation balance and, subsequently, modifying the surface heat fluxes and the stability conditions of the Planetary Boundary Layer (PBL).

An Eppley PSP Pyranometer facing downward was mounted on a small Cessna aircraft and flown along the coastal plain from Tel Aviv to the northern Negev south of Beer Sheva, at an altitude of approximately 500 feet, measuring surface reflection. The incoming solar radiation was measured simultaneously, at several surface radiation stations of the Israel Meteorological Service, along the flight path. The results show large differences in surface reflection distributions, between the cultivated areas in southern Israel (as low as 0.15), and the adjacent arid regions (with values of up to 0.35). Historical albedo maps were reconstructed according to land utilization maps of the 1930's and the 1960's. A comparison between recent albedo map and the reconstructed maps, indicates temporal changes in the surface albedo pattern during the last decades.

1. Introduction

Studies by Alpert and Mandel (1986), Otterman et al. (1990), and Ben-Gai et al. (1993, 1994), have shown that some climatic changes may have occurred in the central and southern parts of the Israeli coastal plain (Fig. 1) during the last three decades: decrease in wind variability, decrease in the difference between day and night temperatures, and increase in early seasonal rainfall patterns.

This area has undergone significant changes in land use during the past decades, especially since the National Water Carrier operation in 1964. There has been a massive increase in cultivation, forestation and urban development. Such changes should be reflected in temporal changes in spatial variability of albedo, evapotranspiration and roughness length.

Otterman (1974), presented a land imagery satellite picture in which the border between the dark Negev and the bright Sinai could clearly be seen. According to Otterman, this was a result of overgrazing in the Sinai desert. In the Negev desert, increased vegetation cover, dormant towards the dry summer season, has decreased albedo, inducing an increase in sensible heat flux (with nearly zero evapotranspiration). According to measurements from an aircraft, Otterman found that air temperatures over the Negev were 4 °C higher than temperatures over the Sinai.

Another explanation for the albedo step across the Sinai border, is the effect of the biogenic soil

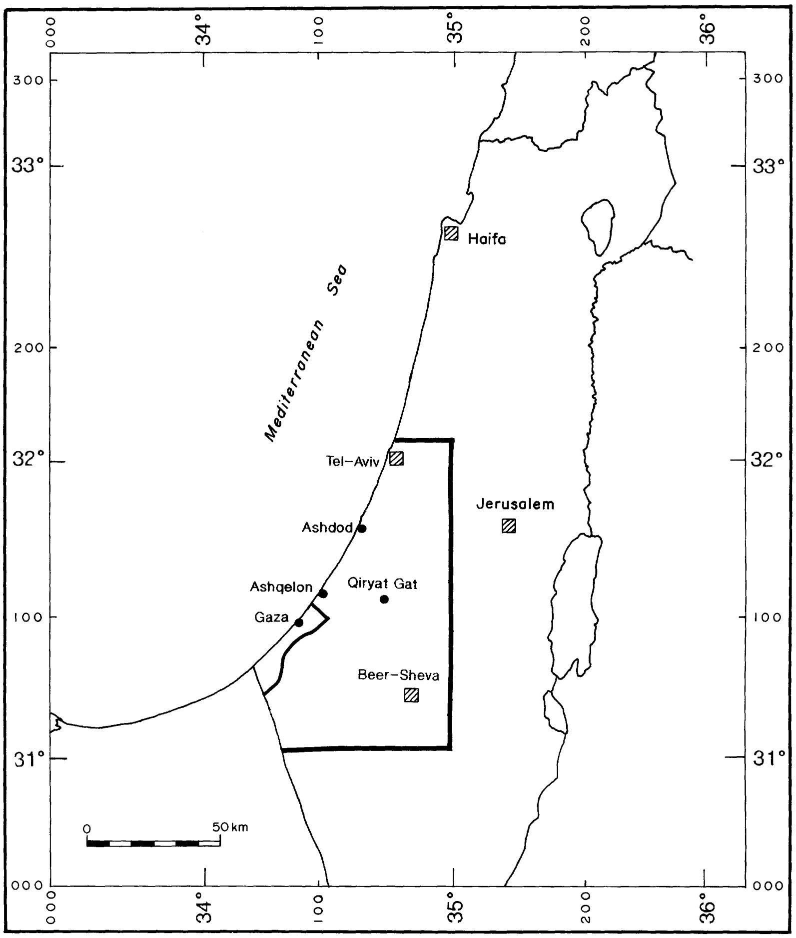

Fig. 1. The study area consisting of central and southern coastal plain of Israel

crust (consisting of mosses, lichens, algae and cyanobacteria), on the satellite reflectance, in arid and semi-arid areas (Karniali, 1995).

In any event, decreasing albedo values over irrigated cultivated areas imply a higher energy budget, which may be transferred to latent heat flux through evapotranspiration. Temperatures over these areas tend to be lower than the dry surroundings (Wendler and Eaton, 1983).

A number of studies were concerned with the way heat fluxes effect thermodynamics and synoptic conditions in the PBL. Sensible heat flux can act as a lifting mechanism and enhance potential instability (Rabin et al., 1990; Segal et al., 1988, 1989, 1994; Dalu and Pielke, 1993). Obviously, latent heat and moisture fluxes play a crucial role in inducing convective activity: they tend to increase dew point, enhance vapor pressure, add moisture to cloud content and contribute to buoyancy by releasing heat through condensation, thus enhancing instability (Anthes, 1984; Brnston and Schickedanz, 1984; Novak, 1990; Rabin et al., 1990; Dalu and Pielke, 1993; Segal et al., 1988, 1989, 1994; Pielke and Avissar, 1990; Pielke et al., 1991)

This mechanism is believed to have caused the frequent penetration of the PBL capping inversion by bearing convective clouds during October. These conditions prevail mainly during October due to the weakening of the subtropical high pressure system prior to the penetration of winter mid-latitude large scale synoptic systems. The eastern Mediterranean is still warm during this period of the year and air masses moving toward the continent become unstable. Local forcing along the coast line could then trigger convective rain.

In this study, reflected solar radiation flux was measured from an aircraft in order to estimate the albedo values of the central and the southern coastal plain of Israel. These values were then applied to maps of different land uses from the 1930's, the 1960's and the 1990's in Israel. Estimations of the temporal changes in the albedo values for the last sixty years enable the estimation of possible temporal changes in heat and moisture fluxes, which may trigger rain.

2. Description of the Experimental Area and Temporal Change in Land Use

The central and southern coastal plain of Israel, between the city of Tel-Aviv (in the northern part of the study area), and the northern Negev, south of Beer Sheva, widens from 25 km to 60 km, respectively (Fig. 1). Except for several urban areas, this region is occupied by agricultural settlements. The only exception being the coastal dunes. The rain season in Israel lasts from October to May, and the average annual amount of rain is 500 mm in the northern part of the study area dropping to 200 mm in the south.

A comparison of land uses maps of early 1930's, 1960's (Atlas of Israel, 1970) and 1990's (Ministry of Agriculture, 1994), enables the characterization of temporal changes in spatial variability of cultivation in the central and southern coastal plain of Israel. It can be observed, in the map for the early 1930's (Fig. 2), that besides plantations, mostly of irrigated citrus (east and southeast of Tel-Aviv), the greater part of the study area was occupied by non-irrigated agriculture. Sporadic Bedouin cultivation was spread from Beer-Sheva northward. Only small patches of land were irrigated. The urban areas were limited in extent.

The map of land utilization in the early 1960's (Fig. 3) shows plantations spreading southward. Nevertheless, irrigated areas were limited. The area denoted as sporadic Bedouin cultivation in the 1930's was replaced by cultivated land, though still as yet mostly non-irrigated.

Land use map of 1990's, Fig. 4, shows that Plantations and irrigated agriculture occupy most of the northern part of the study area. Irrigated and non-irrigated field crops and vegetation dominate the southern part of the study area. According to the Ministry of Agriculture, 1994, over 60% of this region is irrigated, mainly during the summer. Annual amount of irrigation water is 10^6 m^3/y, equivalent to rainfall amount of 100–200 mm/y.

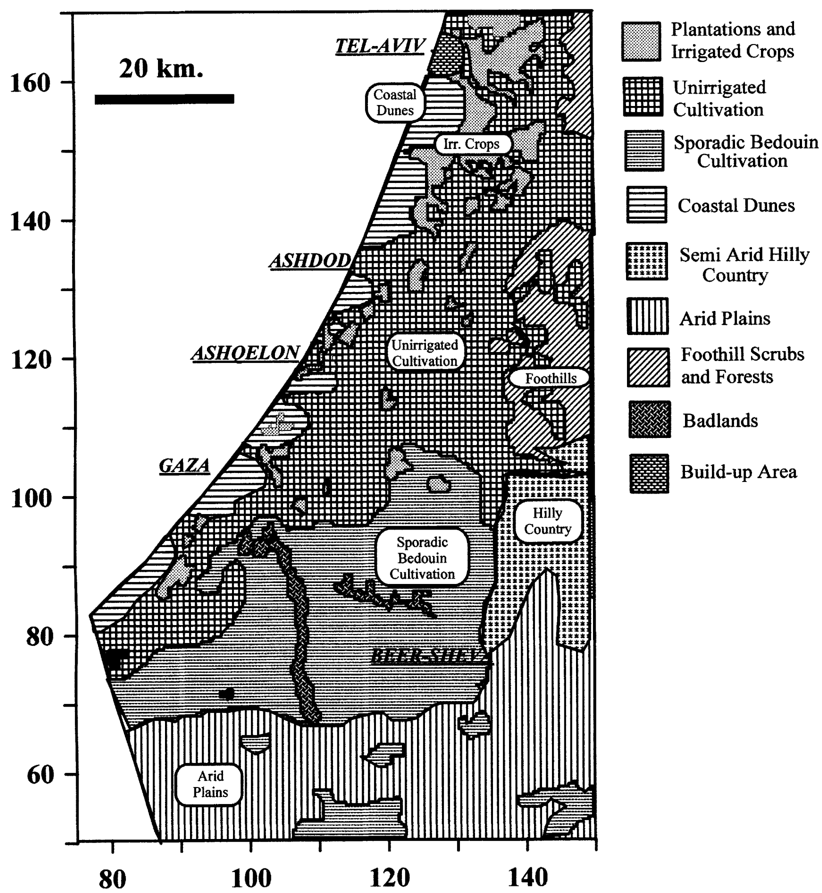

Fig. 2. Land utilization map of the early 1930's. Citrus plantations and irrigated crops are restricted to the northern part of the study area, with some patches southward. Most of the northern part of the study area is covered with unirrigated cultivation. Bedouin sporadic cultivation and arid plains occupy most of the southern part. (Atlas of Israel, 1970)

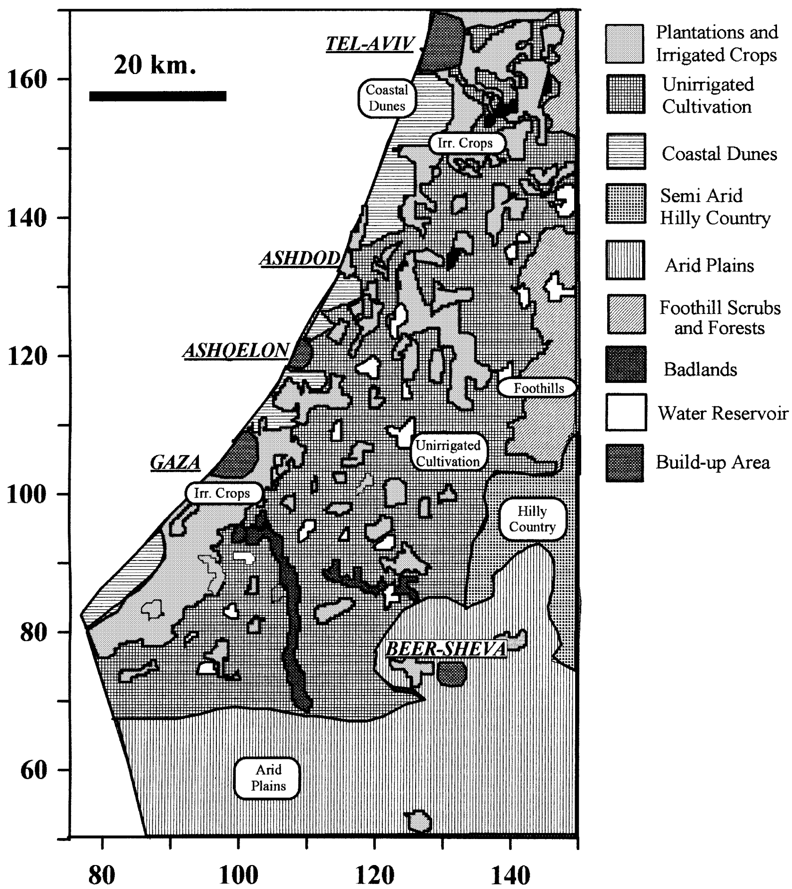

Fig. 3. Land utilization map of early 1960's. Plantations and irrigated crops cover continuous areas in the northern part of the study area and the Gaza strip. Confined areas of irrigated crops, plantations and water reservoirs can be observed, scattered within unirrigated areas covering most of the study area. (Atlas of Israel, 1970)

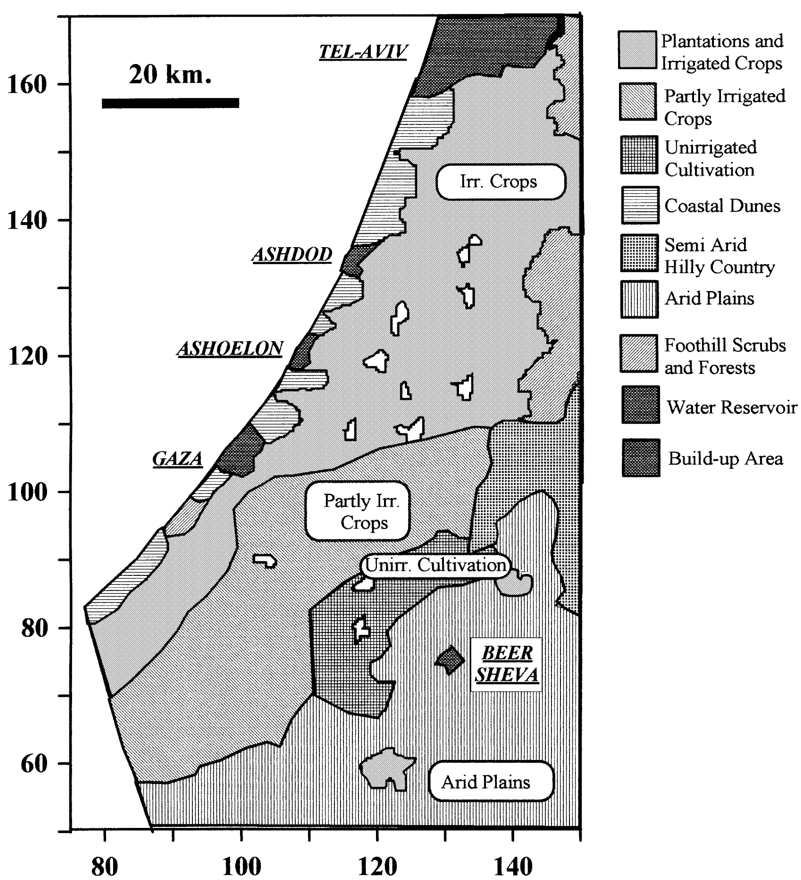

Fig. 4. Land use map of 1990's shows that Plantations and irrigated agriculture occupy most of the northern part of the study area. Irrigated and non-irrigated field crops and vegetation dominate the southern part of the study (Ministry of Agriculture, 1994)

3. Aircraft Measurements

An Eppley Precision Spatial Pyranometer (PSP) facing downward was mounted on a Cessna aircraft and flown along the coastal plain from Hertzliya to Zeelim and Beer-Sheva at an altitude of 500 feet. The Pyranometer measured short-wave reflected radiation from the surface (0.15–3.0 micron). The flight took place on August 8, 1994 between 12.34 and 14.28 local time (09.34 to 11.28 GMT) around mid-day at the highest solar altitude. The Precision Spatial Pyranometer has a 2π viewing angle, and is identical to the Pyranometers measuring the incoming short wave sun and sky radiation at the radiation stations of the Israel Meteorological Service, situated along the path of the aircraft flight. The date and hours of the instrumented Cessna flight were selected carefully to ensure a combination of the following conditions:

(a) Complete clear sky conditions to avoid any interference of cloudiness (simple and multiple scattering).
(b) Conditions of high visibility were selected carefully for the experiment to diminish the effect of haze on surface reflectivity.
(c) Flight around noon to ensure a low solar zenith angle. In Israel, in August, the sun is very close to the zenith.
(d) The flight altitude was selected to be as low as possible (500 feet) to decrease the effect of the atmospheric layer between the surface and the aircraft on the surface reflectivity including also the effect of absorption by water vapor.

Aircraft positioning was obtained by GPS (Global Positioning System) readings of every 4 to 8 minutes, corresponding to 5 to 10 km. A Campbell scientific data logger was used to record the reflected short-wave radiation from the surface. Data was averaged every 20 seconds, so at the speed of 100 knots (180 km/h), the values reflected variations representing a section of 1 km. The incoming solar radiation was measured simultaneously at four surface radiation stations of the Israel Meteorological Service along the flight path (Tal Aviv, Ashdod, Beer Sheva, and Havat Habsor, see Fig. 8). The aircraft mounted downward facing Pyranometer, as well as the surface station's Pyranometers were calibrated in accordance to the calibration practices adopted at the Israel Meteorological Service, traceable to the World Radiation Center (WRC) standard.

To get surface albedo, the reflected radiation was calculated as part of the incoming insolation. Usually, in order to get albedo values, changes in angular and spectral dependence of radiation reflected from the surface, should be taken into account. Since the purpose of this study, however, was to look mainly for the relative reflectance properties of the surface, hence, these corrections were not crucial for the relatively short flight period of two hours.

4. Results and Discussion

The flight path and albedo stations' numbers are shown in Fig. 8 (in the map of spatial distribution of albedo values in the 1990's). Albedo values

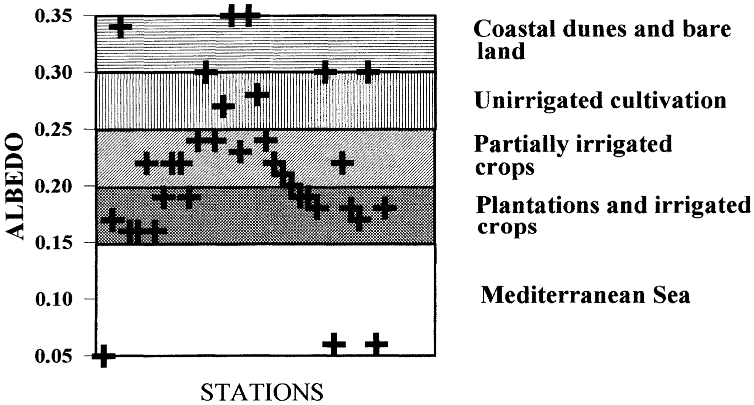

Fig. 5. Sorted albedo values of 34 stations, according to four kinds of land utilization and the Mediterranean Sea. Signs indicate stations along the flight path (see Table 1)

and land use properties descriptions are given in table 1. Since albedo values over Tel-Aviv have not been measured, changes in albedo over this urban area are not considered. As the flight took place around mid-day, albedo values over similar land utilization on any given latitude were found to be the same on the way south and back, as reflectance angle rotates around its maxima.

Albedo values obtained during the flight were sorted into five categories: four of different land uses and the Mediterranean Sea (Fig. 5). As can be observed, the amount of vegetation cover and amount of irrigation are the main factors which effect albedo: values rise as irrigation and areas covered by vegetation are reduced. Plantations and irrigated cultivation have the lowest albedo values (0.15–0.20) over land. The coastal dunes and bare land have the highest (0.30–0.35). Over the sea, albedo values range between 0.05–0.06.

Over the years, changes in land uses can lead to temporal changes of albedo. Historical land utilization maps can be used to trace these changes. Four categories of the albedo values over the land (as were shown in Fig. 5) were applied to land utilization's maps of the early 1930's, 1960's and 1990's in order to find the temporal changes in spatial variability in albedo.

The results are shown in Figs. 6, 7 and 8. The albedo map for the early 1930's (Fig. 6) shows that most of the southern part of the study area (used to be bare land with sporadic Bedouin cultivation) was assumed to have values of 0.30 to 0.35. Albedo values of 0.25 to 0.30 covered most of the northern part of the study area

Table 1. *Albedo Values and Surface Properties Along the Flight Path*

No.	Name	Description	Albedo
1.	Mediterranean Sea	sea	0.05
2.	Jaffa	sea-shore	0.17
3.	Rishon Letzion	dunes	0.34
4.	Rishon Letzion	citrus plantations	0.16
5.	Kfar Hanagid	citrus plantations	0.16
6.	Ashdod refinery	industrial area	0.22
7.	Kfar Silver	citrus plantations	0.16
8.	Ashqelon	suburbs(vegetated)	0.19
9.	Gaza(city)	dispersed houses	0.22
10.	Nuserat	field crops	0.22
11.	Kisufim	irrigated crops	0.19
12.	Ohad	cultivated land	0.24
13.	Zeelim A	scrubs	0.30
14.	Zeelim B	field crops	0.24
15.	Hovav Hieght	disposal area	0.27
16.	Har Naim	bare land	0.35
17.	Beer Sheva (city)	dispersed houses	0.23
18.	Sde Teiman	bare land	0.35
19.	Gilat	plough fields	0.28
20.	Shibolim	field crops	0.24
21.	Saad	field crops	0.22
22.	Mefalsim	irrigated crops	0.21
23.	Or Haner	irrigated crops	0.20
24.	Gevaram	irrigated crops	0.19
25.	Ashqelon (east)	suburbs (vegetated)	0.19
26.	Sde Elyahu	plantations	0.18
27.	Ashdod (East)	dunes	0.30
28	Mediterranean Sea	sea	0.06
29.	Yavne	field crops	0.22
30.	Yavne	plantations	0.18
31.	Rishon Letzion	citrus plantations	0.17
32.	Rishon Letzion	dunes	0.30
33.	Mediterranean Sea	sea	0.06
34.	Glilot	suburb (vegetated)	0.18

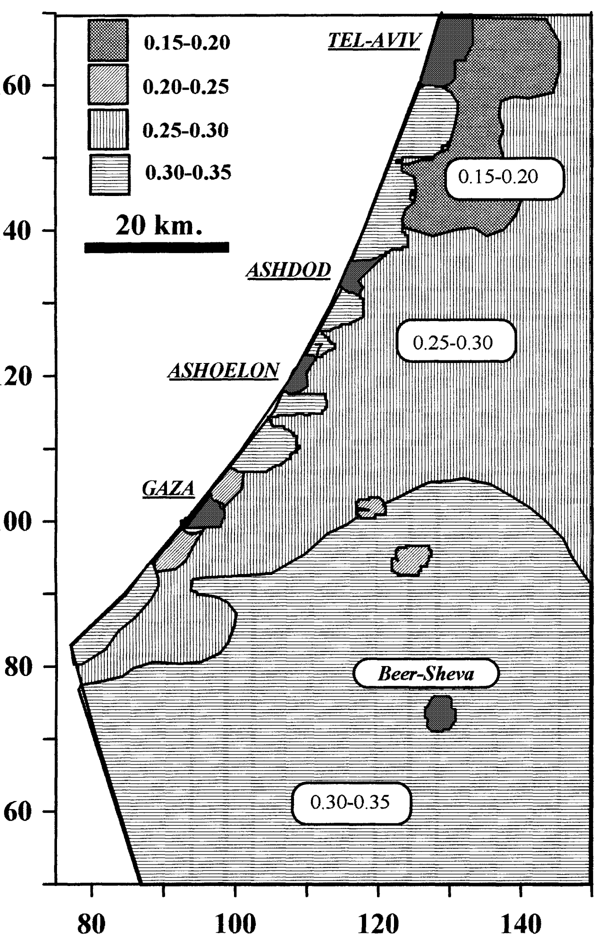

Fig. 6. Reconstructed spatial distribution of albedo values for the early 1930's. Most of the area in the south shows albedo values of 0.30–0.35. Most of the northern part of the study area shows albedo values of 0.25–0.30

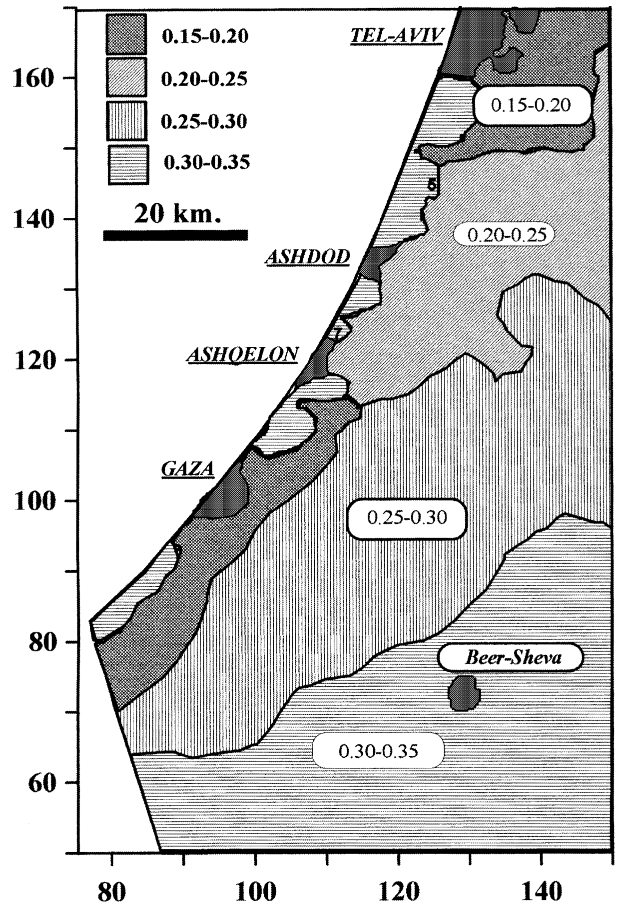

Fig. 7. Reconstructed spatial distribution of albedo values for the early 1960's. Albedo values of 0.30–0.35 cover smaller areas than in the 1930's. Most of the area still retains albedo values of 0.20–0.30

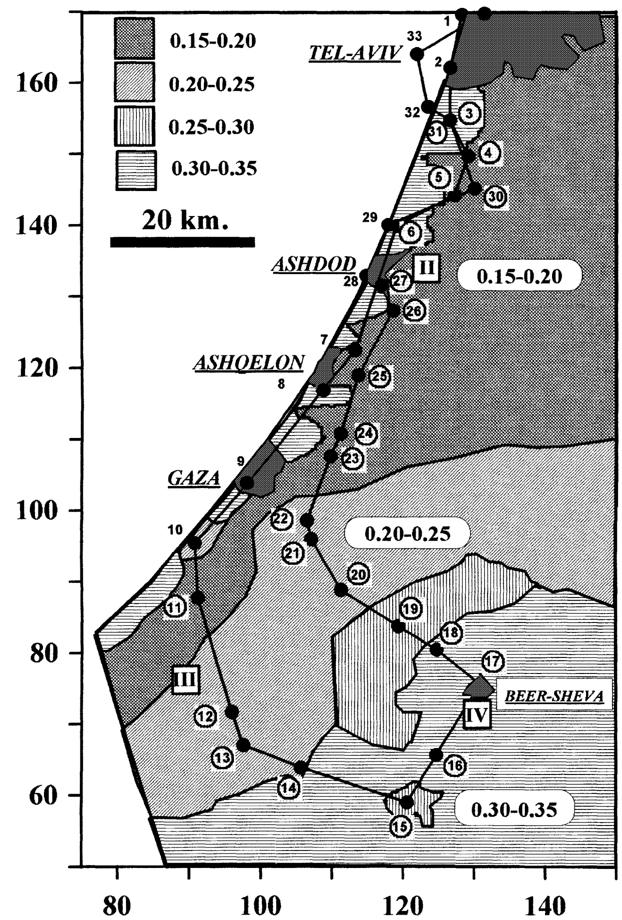

Fig. 8. Spatial distribution of albedo values of the early 1990's. Albedo values of 0.15–0.20 occupy most of the northern part of the study area. Areas with albedo values of 0.30–0.35 are restricted. Flight path and albedo measurement stations (indicated by numbers, see Table 1)

(nonirrigated cultivation). Only small patches within the north (citrus groves) were assumed to have values of 0.15 to 0.20.

The albedo map of the early 1960's (Fig. 7) shows a strip of albedo values estimated to be 0.15 to 0.20 (irrigated crops and plantations) along the coastal dunes, thickening only in the north and along the Gaza Strip. Much of the area supposedly had values of 0.25 to 0.30 (nonirrigated cultivation). Over areas of nonirrigated cultivation with patches of irrigated crops, albedo values were assumed to be lower, ranging between 0.20 to 0.25. The values of 0.30 to 0.35 covered smaller areas than in the 1930's.

The albedo map of the 1990's (Fig. 8) shows that almost all of the northern part of the study area has albedo values of 0.15–0.20, except the coastal dunes and the urbanized regions. The same values can be observed in the southwestern part of the study area. Areas with albedo values of 0.30–0.35 are restricted to the coastal dunes and a limited area surrounding Beer-Sheva.

With the exception of the coastal dunes and the area surrounding the city of Beer-Sheva which remain unchanged, most of the albedo values in the early period were higher by 0.10–0.15 compared with the late period. The most pronounced changes of about 0.15–0.20, took place in the southern part of the study area. This area has undergone the most pronounced changes in the October average rainfall as well as the annual coefficient of variation from as much as 45% in the first period (1938–1962) to 31% in the second period (Ben-Gai et al., 1993; 1994).

Decrease of albedo values indicate higher sensible and latent heat fluxes. Charney (1975) and Segal et al. (1994) claim that lowering of albedo values by the magnitude of 0.2 is significant enough to enhance heat fluxes in a way it may act as a trigger to convective activity and rain, under favorable synoptic conditions.

The atmosphere tends to screen off small changes in spatial variability of heat and moisture fluxes which are less than 10 km in size (Andre et al., 1990). Most researchers tend to agree that the minimum interval of horizontal grid to force convective change is 10 to 20 km (Segal et al., 1988, 1989, 1992, 1994; Mahfouf et al., 1990; Bryant et al., 1990; Dalu and Pielke, 1991; Andre et al., 1990). The wide band of 40 km in the southern part of the study area, where temporal albedo changes are more pronounced, may suggest that air masses coming from the Mediterranean absorb heat and moisture fluxes which are sufficient to significantly modify the air masses.

5. Conclusions

Recent studies imply that significant climatic changes over the central and southern coastal plain in Israel may be due to changes in land usage, which have taken place since the National Water Carrier operation in the early 1960's. Such changes are reflected in the spatial distribution of the surface albedo pattern, obviously resulting in changes in the surface radiation balance and subsequently modifying the surface heat fluxes and the stability conditions of the Planetary Boundary Layer (PBL).

Measuring surface reflection from an aircraft shows large differences in spatial distribution. Reconstructed albedo maps according to land utilization maps of 1930's and 1960's indicate temporal changes in the surface albedo pattern during the last decades.

The most pronounced temporal changes in the reflection values are the decrease in the southern part of the study area. This decrease leads to higher available energy at the surface and may suggest that air masses coming from the Mediterranean absorb energy and moisture fluxes which may be sufficient, under favorable conditions, to trigger rain.

It has been earlier shown that the same area has undergone the most pronounced changes in the October average rainfall as well as the annual coefficient of variation from as much as 45% in the first period (1938–1962) to 31% in the second period.

The albedo maps are subsequently used as input for mesometeorological models, with the purpose of simulating the potential effects of albedo variations on the increase of convection and rainfall in southern Israel.

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