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FOG IN ISRAEL

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ABSTRACT

Synoptic conditions in the eastern Mediterranean, favourable for fog formation in Israel, are discussed by the aid of schematic maps. The diurnal land breeze — sea breeze circulation, together with the presence of subsidence inversions and radiational ground inversions play a decisive role in fog formations in most regions of the country. Topographic influences, local winds and katabatic flow become more important with an increasing distance from the Mediterranean shore. Normal frequencies and duration of fog are given for a number of representative synoptic stations.

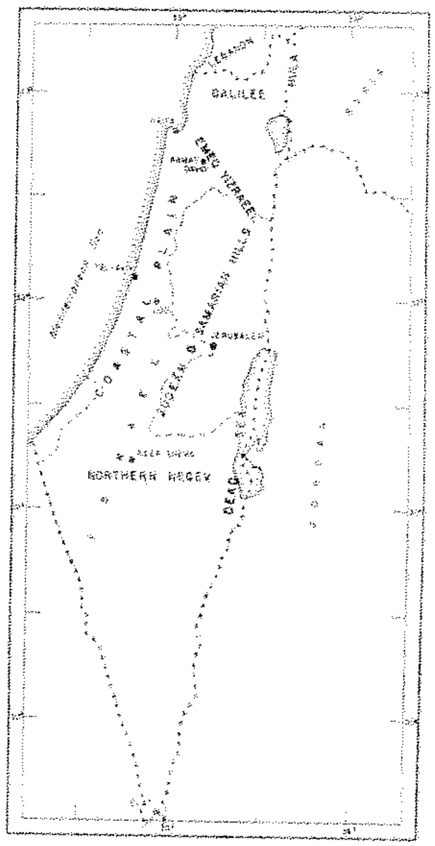

Figure 1

Location map.

INTRODUCTION

The occurrence of fog is of interest not only to meteorologists but also to personnel engaged in aviation operations, agriculture and the traffic police. The phenomenon in our region does not assume the same dimensions as in Europe. Nevertheless, fog at times interferes with aerial and marine transport as well as with traffic. In agriculture fog is of some importance as an additional moisture supply to plants, especially in the semi-arid region. Yet, the prolonged moistening of vegetation also enhances fungus diseases like the Phytophtera of the potato and the tomato.

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CONDITIONS FAVOURABLE FOR FOG FORMATION

Atmospheric Stability

With the increase of the vertical temperature lapse rate the atmospheric stability diminishes and vertical currents and turbulence lead to an exchange of water vapour between the air layers. This exchange favours the distribution of water vapour with height and thus prevents its concentration near the surface which is necessary for the formation of fog. The presence of isothermal layers and/or temperature inversions represent necessary conditions which frequently exist in Israel (Figure 2).

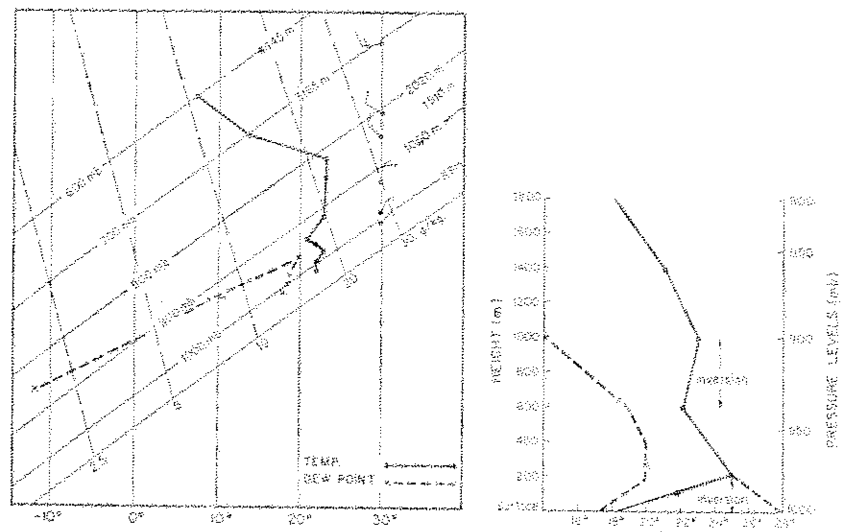

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Figure 2

(a.) Actual radiosonde measurements of the vertical temperature, dew point and wind distribution during a night when fog occurred.

(b.) Schematic temperature and dew point distribution with height during conditions favourable for fog formation.

Figure 2(b.) shows the vertical temperature and dew point distribution under stable conditions. The broken temperature line shows the positive temperature change, i.e., +3 °C in the first 200m at noontime under the influence of convection, whereas the continuous temperature line represents the negative change, or inversion, during the night, −7 °C in the same 200m. In the second and higher

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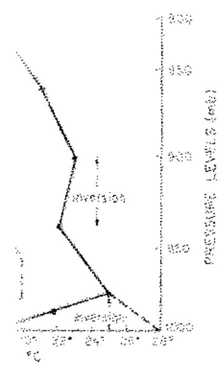

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inversion, between 600 and 1,000m temperature increases only one degree in 400m, and this represents a typical "subsidence inversion". Figure 2(a) shows an actual upper air sounding at 0200 Israel Standard Time, during fog at Be'er Sheva that lasted for 6 hours.

The Presence of Sufficient Water Vapour

In Israel, as a rule, there is sufficient water vapour in the coastal plain because of its closeness to the sea. In the inner parts of the country fog will form only when the sea breeze has penetrated for a sufficient number of hours, after rain, or in certain valleys where local conditions are favourable for its formation.

In the hill region "hill fog" forms, but is actually a low-cloud formation covering the hill-tops (see page 19).

Favourable Radiation Conditions

The prevalent type of fog in Israel is the radiational kind. This type of fog forms whenever the above conditions are fulfilled and good radiation conditions exist. These conditions exist quite often in our region, especially in the summer, when above the ordinary surface inversion a second and usually less strong inversion forms frequently. This second inversion is the result of a sinking motion ("subsidence") of the air in the subtropical summer anticyclone. This layer is also characterised by the abrupt decrease of the absolute and relative humidity at the base of the inversion.

A Very Light Wind

When the surface wind velocity exceeds about 3 kts the increasing turbulence of the flow results in vertical exchange of the cold air near the surface and the warmer air above it, so that the nocturnal inversion is destroyed and effective cooling of the air near the ground prevented. On the other hand, complete absence of wind may cause the moisture to concentrate in a very shallow surface layer, resulting in heavy dew or shallow ground fog, of less than 2m thickness.

A wind exceeding about 3 kts may be observed during advection fog. However, this type of fog is very rare in Israel. Such a surface wind is likely to destroy the lower part of the nocturnal radiation inversion. Thus, the moist layer will be lifted some tens or hundreds of meters and will appear at the base of the remaining inversion where low clouds of the stratus type will then form.

A light westerly or northwesterly breeze in the lowest layers, together with an easterly or north easterly wind above 400m represent an ideal vertical wind distribution for fog formation (Figure 3). The abrupt change in wind direction, which can usually be seen on wind distribution with height, coincides with the base of the subsidence inversion.

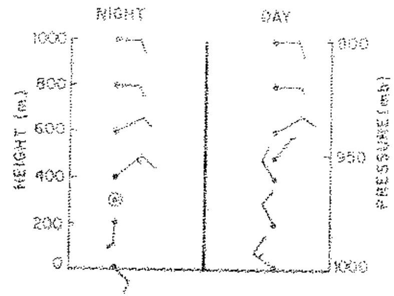

Figure 3
Change of wind with height in the presence of a pronounced temperature inversion and conditions favourable for fog.

Presence of Condensation Nuclei

Theoretically, condensation nuclei are required to promote the condensation of water vapour. However, under ordinary conditions suitable condensation nuclei are never absent in our region, and therefore do not interfere with fog formation. On the contrary — although there is no fear of lethal smogs*, concentrations of industrial plants (such as in Haifa Bay) no doubt enhance fog formation.

TYPICAL SYNOPTIC SITUATIONS

The synoptic conditions — pressure, temperature and moisture distribution in the horizontal and the vertical — which are particularly favourable for fog formation vary according to season. As mentioned above, practically only one type of fog occurs in Israel — the radiational fog, whereas true advection fog, e.g. the one caused by the advection of warm, moist maritime air over cold land, is hardly found at all.

A Warm Upper Anticyclone or a Warm Upper Ridge

In our region, similarly to Europe, widespread fog will form in the presence of a well-pronounced upper ridge or a warm upper anticyclone. This pressure configuration (Figure 5) leads to stable atmospheric conditions, clear skies, the formation of low subsidence inversions that persist sometimes also in the daytime, and light winds. The air in the anticyclonic system subsides, warms and dries out. However, this subsidence does not usually extend down to the surface in the coastal plain. The static weather conditions favour the rise of local wind systems: The sea breeze which during daytime causes the penetration of a shallow layer of moist and relatively

* The expression "smog" has become acceptable in literature for the combination of fog and a high concentration of smoke or other impurities, as it is found in large cities and agglomerations of industry. Cases of heavy smog have become widely known during the last years in London and Los Angeles, where numerous deaths have been attributed to exceptionally heavy concentrations of CO_2, O_3 and sulphurous compounds such as SO_2.

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cool maritime air (Figure 4), and a light landbreeze at night. In the daytime the surface wind blows in this case usually from a westerly to northwesterly direction up to 200-300m height and becomes northeasterly to easterly above that (Figure 3).

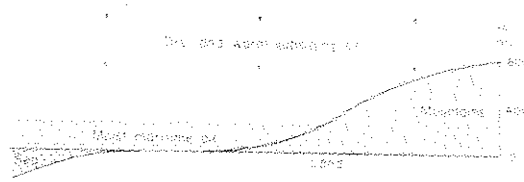


Figure 4
Vertical cross section in the presence of an upper-level anticyclone or an upper ridge over Israel

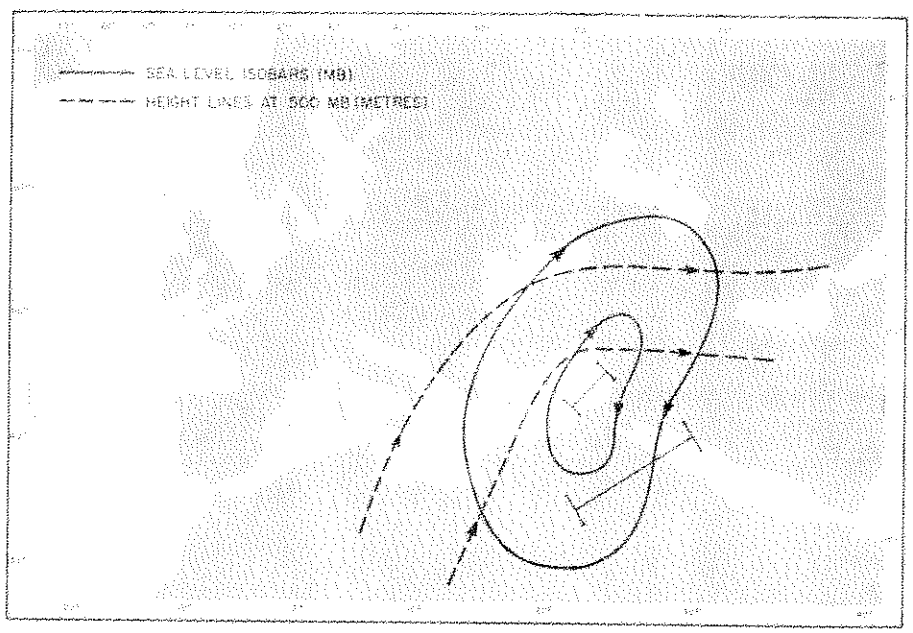


Figure 5
Upper level and surface pressure distribution in the presence of an upper level anticyclone or ridge and a surface high over the region.

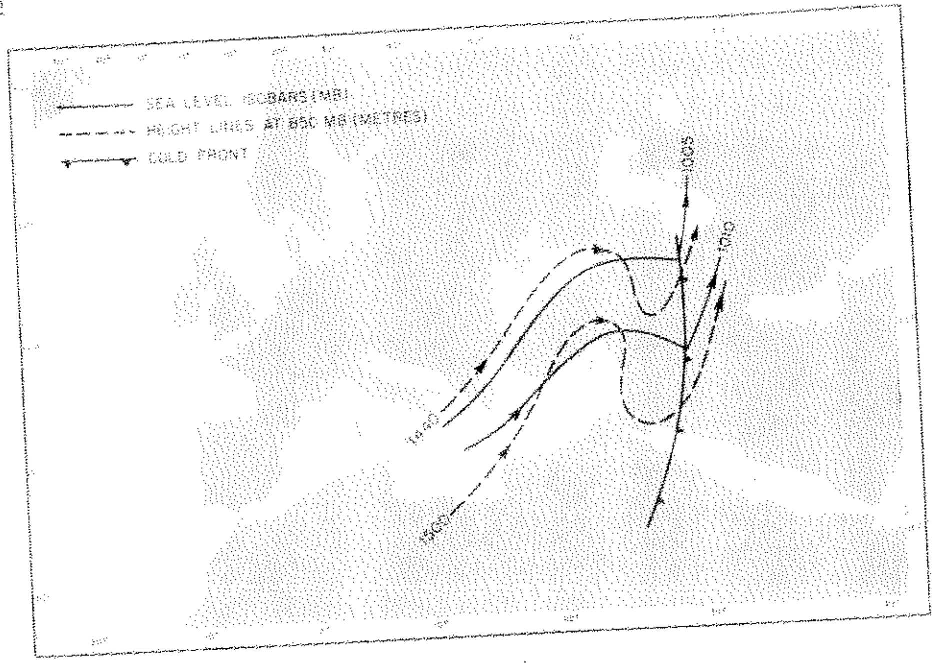


Figure 6
An upper level and surface ridge over Israel following the passage of a cold front.

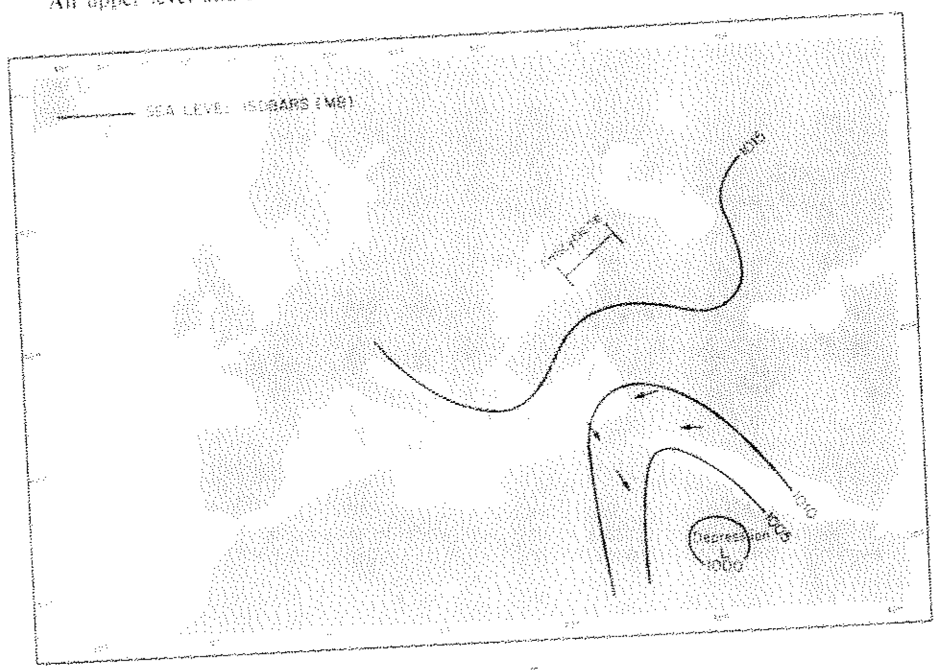
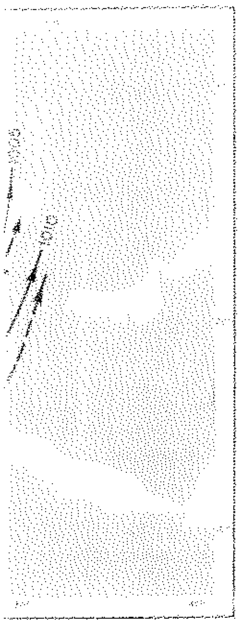


Figure 7
A Sudan trough extending northward to the eastern Mediterranean.



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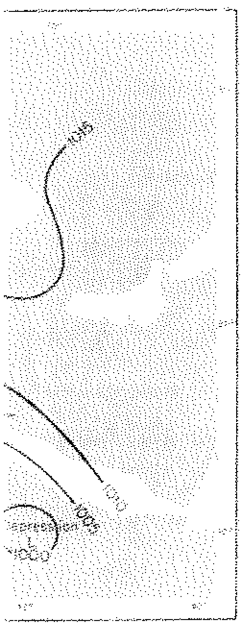

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A Shallow Surface Pressure Ridge in the Wake of a Cold Front

In many instances, the passage of a cold front over Israel is followed by the penetration of a shallow cold ridge occupying the atmospheric layer from the ground up to about 2,000 metres (Figure 6). In such a ridge the following processes can be observed: Cold air subsides and clouds disperse rapidly, especially during night when convection ceases over the land (over the sea cumulus clouds may persist); winds weaken considerably; the air near the ground remains moist from the precipitation that fell and owing to its maritime origin. In winter the longer nights contribute to a more intense radiation.

The Sudan Trough (Red Sea Trough)

During the transition seasons and also, though more rarely, during winter and summer, a surface pressure trough extends from the quasi-permanent low pressure region in the Sudan northwards to our region (Figure 7). In this pressure distribution an easterly or south-easterly surface flow brings relatively warm and usually dry air from the Arabian peninsula, or Jordan, to the inner parts of Israel (the Jordan Rift, the hill region and the inner coastal plain). During daytime the sea breeze prevails over the easterly wind component so that moist maritime air penetrates to the coastal plain. Fog will form only if the dry easterly flow is not too strong to inhibit the formation of the seabreeze. Particularly in the northern valleys, into which the easterly wind can penetrate easily because of their direction, this wind often strengthens especially during the night, and thus prevents the formation of fog.

Synoptic conditions favourable for fog will also arise when the Sudan trough lies with its axis somewhat to the west of the Israel Mediterranean coast, so that warm and dry continental air is advected into Israel. When the trough's axis oscillates eastward to Jordan, Israel falls under its western part, and under the influence of surface winds from a more westerly direction (Figure 8). With the penetration of the moist sea air, together with radiational night cooling fog can form.

Fog in the Wake of a Weak, Dissolving Cold Front

During the transition seasons, but sometimes also in winter, weak cold fronts undergoing frontolysis, pass our country (Figure 9). In this case there will be no precipitation, but only an increased cloudiness of the cumulus or stratocumulus type. The frontal passage will be felt at the surface by temperature drops and particularly by a marked increase in humidity. When the frontal passage occurs during the afternoon or the early hours of the night conditions will stabilise rapidly and together with the large amount of moisture brought in from the sea, they will establish very favourable conditions for the formation of widespread and thick fog in the coastal plain.

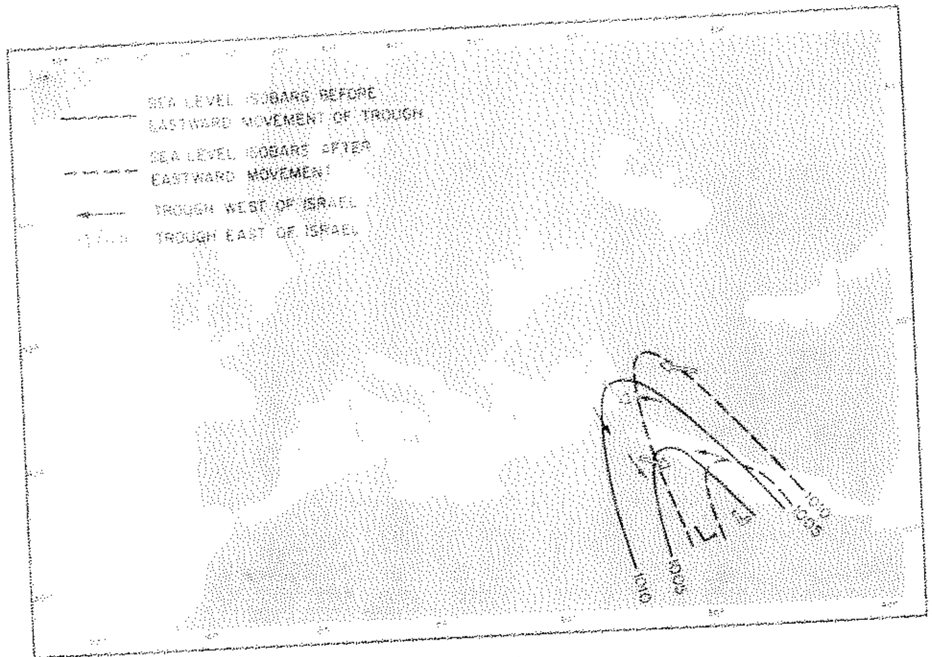

Figure 8
Oscillation of a Sudan trough from west of Israel to the east.

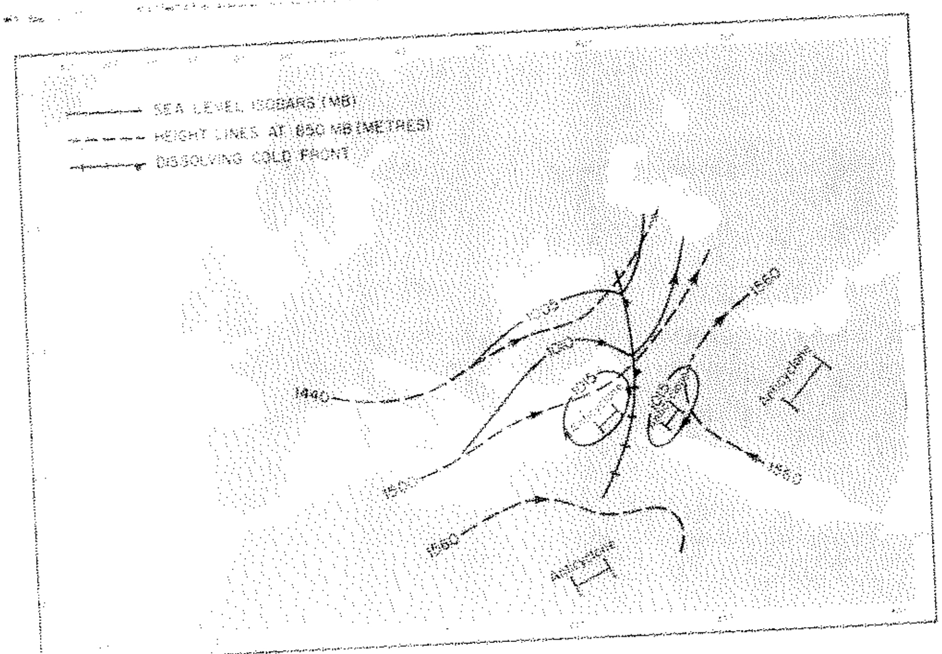

Figure 9
The passage of a disolving cold front.

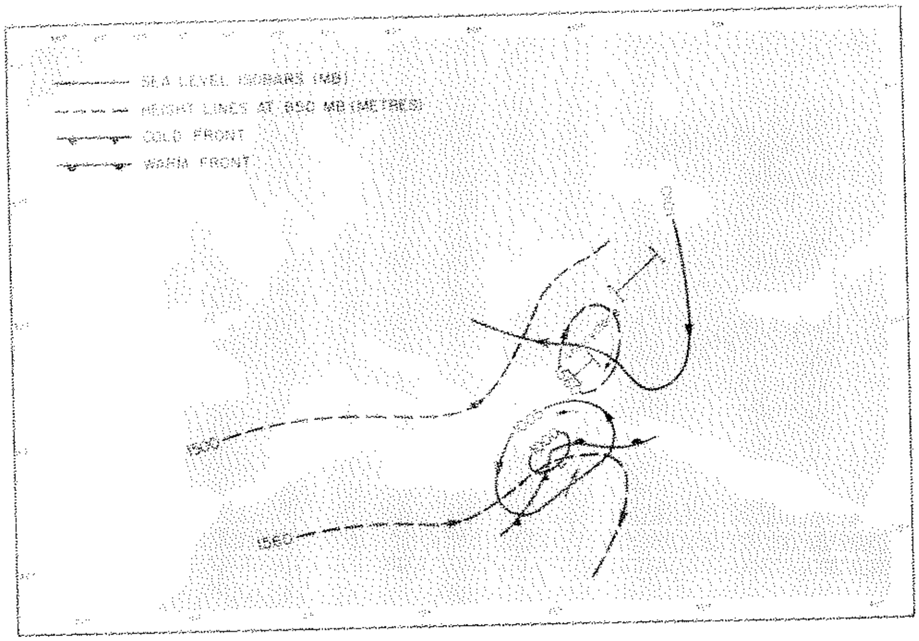

Figure 10
An upper high pressure cell with a surface ridge in front of an advancing Khamsin depression.

An Approaching Khamsin Depression

During the advance of a warm Khamsin depression along the northern coast of Egypt a surface ridge usually exists over Sinai and Israel and then retreats gradually eastwards (Figure 10). This initiates the onset of an easterly or southeasterly flow with light winds at first. Before the arrival of warmer and drier desert air with this southeasterly flow, sufficient moist air remains in the Israel coastal plain to create conditions conducive to fog formation. The advection of warm and dry air usually starts first at a certain height — about 500 to 2,000 meters, while at the surface the pressure gradient still remains sufficiently weak to allow the seabreeze to penetrate during daytime. This differential advection causes stability in the lower layers of the atmosphere while above 2,000 meters usually pronounced instability exists. At that height, middle clouds are likely to form. With the increase of these clouds night radiation will be inhibited and fog formation prevented.

REGIONAL CHARACTERISTICS OF FOG FORMATION

The Coastal Plain

Comparatively speaking, fog is not a frequent occurrence in the coastal plain of Israel. However, its appearance interfers severely with the operation of the Lod International Airport and also with transport on the roads. On the basis of 10 years continuous observations at Lod airport and at Tel Aviv port it is evident that the greatest frequency of fog occurs in the transition season. Table I shows that the highest average occurs in May with 2.6 to 3 foggy nights. It may be stressed, however, that in individual months the frequency may reach 5 nights or even more. During the transition seasons Israel is usually no longer influenced by the passage of strong and well-developed pressure systems, and therefore cloudiness decreases and lighter winds prevail. Moreover, spring is also the time of the appearance of Khamsin lows, and during their movement eastwards favourable conditions for fog are often created. The Sudan trough also extends more frequently northwards during spring, as well as during fall, and as was pointed out above, this pressure configuration often leads to fog formation in the coastal plain. To this last cause, and also to the tendency for the formation of upper level ridges and anti-

TABLE I

Average number of foggy nights (1951—1960)*

Regions and Stations							
Hills		*Hula Valley*	*Northern Negev*	*Emeq Yizreel*	*Coastal Plain*		
Jerusalem	*Har Kenaan*	*Kefar Blum* (1956-1965)	*Be'er Sheva* (1958-1965)	*Ramat David*	*Lod Airport*	*Tel Aviv Port*	*Month*
3.1	9.7	4.8	1.9	5.7	0.7	0.5	January
4.2	6.9	1.5	2.4	6.7	1.2	1.7	February
2.1	5.9	1.2	2.1	7.1	1.1	1.4	March
2.0	3.7	0.7	1.6	7.9	2.5	2.2	April
0.8	1.6	0.1	3.4	5.4	2.6	3.0	May
1.0	0.6	..	4.8	4.6	2.3	2.3	June
1.8	0.8	..	5.9	3.8	1.4	1.3	July
2.4	0.7	..	7.6	2.5	0.9	0.9	August
2.0	0.8	..	3.0	1.2	0.2	0.4	September
0.5	1.2	0.6	4.8	2.2	1.5	1.4	October
2.3	3.8	0.8	3.6	3.1	0.5	0.2	November
3.8	8.3	3.2	1.2	3.7	0.5	0.4	December

* Source : Katsnelson, 1966.

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l Plain	
Tel Aviv Port	*Month*
0.5	January
1.7	February
1.4	March
2.2	April
3.0	May
2.3	June
1.3	July
0.9	August
0.4	September
1.4	October
0.2	November
0.4	December

cyclones, we may attribute the appearance of a secondary seasonal maximum wit an average of 1.5 nights of fog during October.

The characteristics of fog in the coastal plain are those of typical radiation fog, apart from some isolated instances when the fog spreads downwind for some distance under the influence of the landbreeze. It is of interest that in quite a number of instances fog ensues after low clouds of the stratus type form below 300m when a typical subsidence inversion exists, also usually in the daytime. With some turbulence these clouds may lower — sometimes within a quarter of an hour or even less — till they reach the ground, appearing as fog. The average duration of fog is 2-4 hours. It forms, as a rule, after midnight and disperses about one to two hours after sunrise with the heating of the ground. But quite often the fog becomes temporarily denser, precisely after sunrise, as a result of the slight turbulence created by the warming of the air layer near the ground.

On rare occasions, true advection fog appears at the sea shore, when moist maritime air is advected with a westerly wind towards the land, but the resulting fog only penetrates some 2-3 kilometers landwards.

This usually happens at about 1000-1200 Israel St. Time and the phenomenon very seldom lasts more than one hour, but the sight of the milky white mass of fog advancing like a solid wall and rapidly blotting out the landscape is quite impressive.

One could question why fog occurs so relatively rarely in summer in the coastal plain when most conditions seem very favourable for its formation through all the summer: Clear skies; light winds; a stable stratification of the atmosphere at night, i.e. a radiational inversion and often also a subsidence inversion connected with the subtropical anticyclone; sufficient moisture which penetrates with the diurnal seabreeze. Schwarz (1956) found that the "optimal" height of base of the subsidence inversion for the formation of low stratus clouds is below about 400m and above 100 m. Since fog formation requires an inversion extending even lower or at least similar to that, it is clear that the ordinary summer subsidence inversion which extends between about 500-1,000m (Neumann, 1952) will not sufficiently influence the surface cooling. An additional factor is the relative shortness of nights in summer which does not allow the radiational cooling to proceed long enough.

Emeq Yizreel

Night or morning fogs are rather frequent in the northern valleys to which the diurnal seabreeze has easy access. Emeq Yizreel, or in brief "Emeq", will serve well as an example. Continuous three-hourly, and partly hourly observations for Ramat David, are available for 10 years (1951—1960) in Table I. They show that fog is three times as frequent in the Emeq as in the coastal plain. The highest average occurrence is in the early spring months, March and April, with more than seven foggy nights. Very few fogs occur in summer and a minimum appears in September (1.2 nights).

The geographical direction of the valley from northwest to south-east allows easy access to winds from these directions. Thus, the Emeq is particularly influenced by the south-easterly winds that blow in front of Khamsin depressions. These become reinforced more than in other parts of the country by the "valley effect" or the "Venturi" effect.* Thus there are no favourable conditions for fog formation when a Khamsin depression is approaching or during the "Sharkieh" or "Qadim" — the dry easterly wind prevailing at times during the winter.

In contrast, minimum temperatures reach relatively low values in the Emeq compared with other parts of the country. The geographical configuration of a valley generally contributes to increased nocturnal cooling because of the downward flow of radiationally cooled air from the slopes (the katabatic wind). Thus the air at the bottom of the valley can rapidly reach saturation and condensation in the form of fog. Moreover a surface pressure ridge — in contrast to conditions enhancing fog in the coastal plain — should be situated more to the south of the Emeq in order to allow the free penetration of the diurnal seabreeze while a surface ridge to the north would allow a more easterly and drier surface flow to prevail in the valley.**

The Northern Negev

No three-hourly observations and no night observations are available for the northwestern part of the Negev, but it is safe to assume that the fog regime in the region near the Gaza strip and all along the coast to El Arish is similar to that of the Israel coastal plain, i.e. with two maxima during the transition seasons, since the general climatic and topographic conditions are similar.

Reliable three-hourly observations and special observations of deterioration and improvement of visibility at Be'er Sheva are available. Hence, a good picture of the temporal distribution of fog in this area can be obtained (Table I).

The fog regime in the Be'er Sheva area is radically different from that in other regions. The maximum occurrence is in summer — June, July and August, with a secondary maximum in October. There are two possible reasons for this. As was pointed out by Margolin (1964) during June to August a surface ridge extending from the Azores anticyclone to the southern part of the eastern Mediterranean through Egypt is also marked in the northern Negev, particularly during night under the strong radiational influence characteristic for the Negev. This ridge enhances the atmospheric stability and causes to some extent an easterly to northeasterly wind at night at some height above the surface and up to about 1,500m, with a resultant tendency to the drying out of this layer. But still more important may be the fact that the base of the seasonal subsidence inversion is there between

* This effect causes the acceleration of flow in a fluid or gas when it is forced to pass a narrow tube.

** According to S. Nathan [unpublished study of fog at Ramat David (Israel Meteorological Service)].

500 to 1,500m, and is therefore nearer to the surface, which is at about 300m above sea level. In every case of the strengthening of an upper ridge over our region the base of this inversion will tend to lower, thus causing increasingly better conditions for fog formation.

A contributary cause may also be the geographical configuration of this sub-region. As a topographical depression — even more than a valley — enhances katabatic currents along the slopes the downflow of cool air during the night from the ridges to the north and to the south will promote a rapid cooling of the air layer in the Be'er Sheva region. Katsnelson (1966) points out that the daily range of temperature is among the largest in this country. It amounts to more than 15°C average in May, June and August. Thus, the minimum temperature reaches relatively low values (average for August — 18°C (Isr. Met. Ser., 1961)). Therefore the surface air reaches saturation more easily and earlier in the night than in the coastal plain where the average minimum for August is 20°C.

The Hula Valley

In contrast to the fog regime in the northern Negev, fog occurs in the Hula Valley mainly in winter. In this region the seabreeze does not appear as a cool, moisture-laden wind but it descends from the hills of Galilee as a westerly, northwesterly or northerly warm and dry breeze during the afternoon and evening. But on windless and clear winter nights — especially during the prevalence of a barometric high or ridge — cold air drains into the valley from the surrounding ridges of the west and east (Ashbel, 1951). The surface air reaches saturation, and thick fog forms which sometimes persists even for some hours after sunrise, though as a rule fogs disperse with the heating of the ground during the early hours of the morning. The sight of the arms of fog creeping up the slopes, and especially in the crevices which are warmed earlier by the sun under the influence of anabatic currents* is interesting.

Averages for Kefar Blum over 10 years (1956-1965), presented in Table I, show that the highest occurrence of nights with fog to in January with 4.8. In the summer months June-August there is no fog at all. It must be mentioned however, that these averages were prepared on the basis of non-synoptic observations and no night observations, so that it will be reasonable to assume that the figures represent an underestimate although they give a good idea of the general distribution.

The Hill Region

Fog that covers the hill-tops of the Galilee, the Judean and Samarian hills, is not fog in the usual sense of the term but rather clouds of the types stratus, stratocumulus or fractocumulus. Although its physical composition may be somewhat different as water drops in fog are in many instances larger than in clouds, their

* Anabatic wind: an up-slope wind under the influence of diurnal heating.

effect is in practice the same as in fog: A serious deterioration of the visibility and a consequent danger to transport. The number of occurrences of fog in the hills must be intimately connected with the altitude, apart from the moisture sources of the region concerned. The higher the place — although not higher than the average height of occurrence of the above mentioned cloud types, i.e. between some 300—1,500m — the more frequently fog will occur. Averages of Table I show that on Har Kenaan, for instance, there are 44 nights with fog per year, while for Jerusalem the number is only 26. At all events one can probably attribute nearly all fog occurrences in the hills to the presence of clouds, as the topographical configuration does not allow formation of radiation fog.

THE DURATION OF FOG

There are no continuous records of fog duration, but from three-hourly, hourly observations as well as from special deterioration and improvement messages prepared for aviation a fairly good representation may be achieved. Such observations are prepared at Lod Airport, Ramat David and Be'er Sheva for the aviation. On the basis of these observations one can conclude that on the average, fog persists between two to four hours (Table II). It is important, however, to stress that in individual cases fog may persist up to 12 hours or even more, e.g. after the passage of a dissolving cold front. Table II shows average fog duration for each of the above three stations.

TABLE II

AVERAGE FOG DURATION (HR.)

Fog with visibility ≦ 1,000m

Station and Period	*Month* 1	2	3	4	5	6	7	8	9	10	11	12	*Year*	*Extreme (date)*
Be'er Sheva 1958—1965	2.00	2.75	2.00	1.50	2.50	2.00	2.75	1.75	2.25	3.00	3.25	2.50	2.25	13.00 (14.1.58)
Ramat David 1957—1965	4.00	2.25	2.25	3.00	3.00	2.50	2.50	2.25	..	2.50	1.75	3.00	2.50	12.00 (18.1.61)
Lod, Airport 1956—1965	2.00	3.50	3.25	2.00	3.00	2.50	2.25	1.50	0.25	2.50	2.00	1.00	2.00	10.25 (21.2.57)

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	11	12	Year	Extreme (date)
0	3.25	2.50	2.25	13.00 (14.1.58)
0	1.75	3.00	2.50	12.00 (18.1.61)
0	2.00	1.00	2.00	10.25 (21.2.57)

The above table was computed on the basis of cases with 1,000 meters or less visibility only, in order to include only those instances where the reduced visibility presented a severe restriction to transport. Data were used for years in which three-hourly and/or hourly observations and special deterioration and improvement messages were prepared. Those cases with only one observation of 1,000 meters visibility or less were eliminated. The number of years may not yet be sufficient for a precise picture, but a good estimate of the general distribution of fog duration was obtained. In the annual averages of fog duration there is only little difference between the three stations used: In all of them the annual average duration is between 2.00 to 2.45 hours, but the extreme values are very much higher. To take also an intermediate duration value: The total number of cases with duration $\geqslant$ 5 hours was for Be'er Sheva 26, for Lod Airport 9 and for Ramat David 19 for the 1958—1965 period.

Average durations $>$3 hours, are shown in Table II for Lod in February and March, for Ramat David in January and for Be'er Sheva in November — i.e., not particularly in the months which have the highest average occurrence. The lowest average duration occurs for Lod in September (as does also the lowest average occurrence), for Ramat David in November (in September it is, of course, zero as there were no cases of fog) and for Be'er Sheva in April, where there is also one minimum of occurrence, the other falling in December.

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