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The city of Thessaloniki lies amphitheatrically built on the recess of the inner Thermaikos Gulf, at the northwestern coasts of the Aegean Sea. The Meteorological Station of the University, on whose observations is mainly based the present paper, is situated at a distance of about 950m. from the coast, at an altitude of almost 45 m. (Hb = 46m33), and its coordinates are: $\varphi = 40° 37'$ N, and $\lambda = 20° 57'$ E.

Its natural horizon extends westwards from the south to the northwest, at distances varying from 61 km to 104 km, and is confined by the mountain chain of Olympus - Vermion - Pierria, and mounts Ossa and Paikon, while iu the remaining directions it is confined to distances of 1850 to 1450 m., by the walls of the old Acropolis, and the low hills of Oraiokastron, Asvestokhorion, Mikron Emvolon, and the low mountains Khortiatis and Kissos.

Into the Thermaikos Gulf, coming from Yougoslavia, flows the Axios (Vardar) river, whose low, trenched valley enables cold cP air masses to reach Thessaloniki, and even southern down.

In the area of Thessaloniki, as well as in the whole Hellenic area, of paramount importance for the reduction of horizontal visibility, are mainly the water - vapor condensations near the ground (fogs), and atmospheric precipitation.

Consequently, in studying weather conditions causing reduction of the horizontal visibility in Thessaloniki, we examine — for the period from January 1, 1952 till December 31, 1962 — cases during which the visibility range for two, at least, adjoining ten - degree arches of the area visible from the Met. Station, has been ≦ 2000 m. These cases are examined in context with meteorological parameters, whose values we obtained from the Meteorological Stations of tbe University of Thessaloniki, and also with the prevailing during each case weather types, for which we have followed the classification developed by Mr G. L i v a d a s.

TABLE I

	Cause of low visibility	⩽2000 m. 0600	0600→1200	1200	⩽1000 m. 0600	0600→1200	1200	⩽500 m. 0600	0600→1200	1200
Fog	≡	464	71	86	368	31	47	110	8	17
	Total	464	71	86	268	31	47	110	8	17
Fog and other phenomena	≡+●	23		10	15		7	9		5
	≡+●	12	12	5	8	9	1	2	2	—
	≡+✳	5		1	2		1	1		—
	≡+∞	48		1	24		—	4		—
	Total	88	12	17	49	9	9	16	2	5
Phenomena without fog	●	14		16	7		4	1		—
	●	—		1	—		1	—		—
	✳	14	9	9	10	4	4	1	1	—
	Dust	2		1	1		1	—		—
	Total	30	9	27	18	4	10	2	1	0
	Grand Total	582	92	130	335	44	66	128	11	22
	%		22,3			19,7			17,2	

Material: A total of 712 cases have been recorded in Thessaloniki during the above mentioned period, with visibilities $\leqq$ 2000 m. Of these, 582 cases have been recorded at 0600 GMT (morning observation), and the remaining 130 cases at 1200 GMT (midday observation). It should be mentioned that 92 cases of the 130 mentioned above, have been first recorded at 0600 GMT, but having maintained low - visibility conditions afteı 0600 GMT and till 1200 GMT, they have been recorded again; the reduction of visibility has started after 0600 GMT in 38 cases only.

Moreover, the total of cases has been devided in the following three groups, according to the cause of low visibility:

A. Fog only.

B. Fog and other phenomena.

C. Other phenomena, without any fog.

Finally, from the total of cases, we have chosen and set in special groups (repeating them) cases showing reduction of the visibility to $\leqq$ 1000 m. or to $\leqq$ 500 m.

The above are contained in Table 1.

From the above we draw the following conclusions:

— Out of a total of 582 cases with visibility $\leqq$ 2000 m. recorded at 0600 GMT, 464 cases (79,7 %) are due to fog only, while 88 cases (15,1 %) are due to the presence of fog with other coexisting phenomena. Which means that, out of 582 cases at 0600 GMT, in 552 cases (94,8 %) the low visibility was caused by fog (alone or with other phenomena).

— Moreover, out of 130 cases recorded at 1200 GMT, in 103 cases (86 due to fog and 17 due to fog with other phenomena, or 79,2 %) low visibilities are due to fog (alone or with other phenomena).

— As already mentioned, in 38 cases only, the reduction of visibility has started after 0600 GMT, that is on a total of 620 cases (582 at 0600 GMT and 38 at 1200 GMT), only 6,1 % have shown reduction of the visibility after 0600 GMT.

— Finally, out of 582 cases recorded at 0600 GMT (regardless of cause), in 335 cases only (57,6 %) the visibility has been lowered to $\leqq$ 1000 m., and 128 cases (22,0 %) had visibilities of $\leqq$ 500 m.

From the above mentioned, it is quite clear that fog is the main cause of low visibilities in Thessaloniki (alone or with other phenomena), and also that the majority of cases occur in this area during the morning.

Consequently we have limited our study to cases of low visibility of $\leqq$ 2000 m., recorded at 0600 GMT, and causes by fog or fog with other phenomena.

TABLE II

Month	I	II	III	IV	V	VI	VII	VIII	IX	Xa	Xb	XI	XII	Total	%
A. Due to fog only															
S		2				1					1			4	0,9
O	5	1	6	3				1	2				1	19	4,1
N	14	7	3	2		5	6	3	2		1		8	51	11,0
D	21	29	6	3		9	11	12	6	1		1	16	115	24,8
J	17	25	9	5	1	20	11	11	12	3	2		6	122	26,3
F	15	8	7	4	2	12	6	7	6	1			11	79	17,0
M	10	13	2			6	7	7	9	1	2	1	3	61	13,1
A	1			2		3		1	4				2	13	2,8
Total	83	85	33	19	3	56	41	42	41	6	6	2	47	464	100,0
%	17,9	18,3	7,1	4,1	0,6	12,1	8,8	9,1	8,8	1,3	1,3	0,4	10,1	99,9	
B. Due to fog and other phenomena															
S	1	3				2		1	1		3			11	2,0
O	6	3	6	5				1	2				2	25	4,5
N	15	12	3	3		5	7	4	2		1		8	60	10,9
D	22	33	7	3		14	12	15	7	1	1	1	21	137	24,8
J	21	26	11	5	1	23	13	12	12	4	3	1	7	139	25,2
F	18	10	9	4	2	15	7	9	6	1	1		13	95	17,2
M	12	13	2			8	7	9	11	2	2	1	3	70	12,7
A	1			3		4		1	4				2	15	2,7
Total	96	100	38	23	3	71	46	52	45	8	11	3	56	552	100,0
%	17,4	18,1	6,9	4,2	0,5	12,9	8,3	9,4	8,2	1,4	1,9	0,5	10,1	100,2	

Frequencies:

— Low visibility cases occur in the examined area mainly during the eight month period from September till April.

During the warm season (from May till August), a few cases of low horizontal visibility have been recorded, mainly during the first 5′ or 10′ of summer showers: the lowering of the visibility has been caused by the evaporation of rain - drops on touching the warm ground.

However, these cases, besides being of very short duration (since their cause ceased existing after 5′ or 10′ from the beginning of the rain-fall), they did not fill the basic requirements as to their extent, since they all covered arches of visibility of $<20°$.

One case only, filling the standard requirements that we set at the beginning of this paper, has been recorded during the whole period e-xamined, in the warm season, and specifically on August 13, 1956. This was exclusively due to a dust-storm, caused by a sudden gusty wind (4,4 m/sec), and following an one-month period of drought.

In Table II, we give the frequencies of cases, for each month.

— The month of January has the highest frequency of cases (122 due to ≡, 139 due to ≡ or ≡ + other phenomena), December comes next with a small difference (115 and 137 cases respectively) and follow with a greater difference the months of: February (79 and 95 cases), March (61 and 70 cases) and November (51 and 60). A few cases appear in Octo-ber (19 and 25 cases), and April (13 and 15 cases). September comes last with a very small frequency (4 and 11 cases).

We can see thus, that as we advance towards the cold season, the frequency of cases of low visibility is getting higher, with a maximum during the properly winter month (at least in our latitude) of January. It should be noted that the calendar winter trimester of Desember - January - February, accumulate 68,1 % of the total of cases due to fog or fog and other phenomena.

The frequency curve for each month is given in Diagram 1

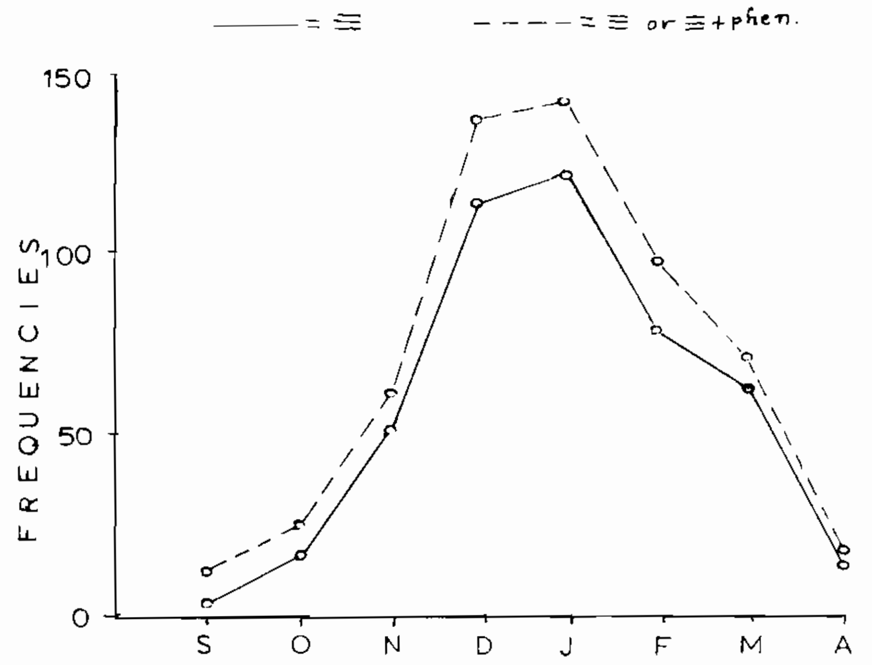
The frequency curve for cases of low visibility, is almost the same, whether it concerns cases due to fog, and cases due to fog or fog and other phenomena.

This curve is skewed to the left (negative skewness) and presents: arithmetic mean of 58 and 69 respectively, and median of 118,5 and 138,0 respectively.

Influence of weather types on the formation of fogs.

If we consider the above mentioned classification of weather - types (LIVADAS, 1962) as well as the type of fog that is favored by each

DIAGRAM I



weather - type (V. ANGOURIDAKIS, 1966) we can classify the types of fog usually encountered in the area of Thessaloniki, in six general groups.

(a) Warm invasion fogs: W.T. III
(b) Cold invasion fogs (extremely rare) combined with extreme weather conditions (Steam - fog: KYRIAZOPOULOS - LIVADAS, 1961).
(c) Warm front fogs: W.T. VI, XII.
(d) Cold front fogs: W.T. I, VII, Xb.
(e) Radiation fogs: W.T. II, IV, V, VIII, IX, Xa.
(f) Weather Type XI: This type does'nt favor the formation of fog in Thessaloniki.

Based upon the above classification, and Tables I and II, we have composed the T a b l e III, which gives the absolute values and the percentage quota of each one of the above groups, in the occurence of fogs, fogs with haze, fogs with precipitation, and fogs with other phenomena in general.

(a) C a s e s d u e t o f o g. The group of radiation fogs (ground fogs) covers 42,2 % of the total of cases due to fog only. This high percentage is mainly due to the fact that all weather - types of this group combine the most favorable conditions for the formation of fog, that is: clear or clearing sky, and calm or light air.

The second and third places are held by the cold front (27,6 %) and warm front (22,2 %) groups respectively. This means that frontal fogs in general, cover ½ of all the cases recorded during the period examined, that were due to fog only (49,8 %). The frequent disturbances during the eight - month period examined, account for the high percentage of fog with prevailing weather - types of these two groups.

Weather Type III (w a r m i n v a s i o n g r o u p) gives 7,1 % of the total of fog, but if we take into account the small frequency of this weather - type, it can be considered as one of the most favorable for the formation of fog in this area. As a matter of fact, when this weather - type prevails, warm air masses from the Aegean Sea (and consequently humid) arriving over the cold, at this season, coast, develop conditions favorable to the formation of fogs.

Weather Type XI (Vardharis wind) has only two cases due to fog, during the whole examined period.

Finally come the two cases of group (B), both due to the very rare condition of c o l d i n v a s i o n.

(b) C a s e s d u e t o f o g a n d o t h e r p h e n o m e n a. The radiation weather - type group covers 68,8 % of the total of cases due to ≡ +∞ and only 5,0 % of the total of cases due to ≡ | precipitation. This should be expected, since when weather - types of this group prevail, they entail clear or clearing sky, and calm or light air.

The group of the frontal weather - type is to the contrary effect. As a matter of fact, frontal fogs (warm and cold front) cover 27,0 % of the total of cases due to ≡ +∞, while they cover 85,0 % of the total of cases due to ≡ + precipitation. The reason for this is given by the mechanism of frontal fogs in itself. Frontal fogs are really precipitation fogs (formed by cooling or by saturation through increasing the water content).

TABLE III

Weather Types	≡	%	≡+∞	%	≡+prec.	%	≡÷phen.	%
III	33	7,1	1	2,1	4	10,0	5	5,7
Steam - fog	2	0,4	—	—	—	—	—	—
II, IV, V, VIII, IX, Xa	196	42,2	33	68,8	2	5,0	35	39,8
VI, XII	103	22,2	4	8,3	20	50,0	24	27,3
I, VII, Xb	128	27,6	9	18,7	14	35,0	23	26,1
XI	2	0,4	1	2,1	—	—	1	1,1
Total	464	99,9	48	100,0	40	100,0	88	100,0

L o w V i s i b i l i t y C o n d i t i o n s. As we have already mentioned at the beginning, low visibilities in Thessaloniki are mainly due to fog. Its formation however depends on dynamic causes (weather - types) as well as on the thermal and hygrometric conditions of the atmosphere. Thus conditions favorable to the formation of fog, are the following:

— Cooling of the air mass without subsequent change in the quantity of water vapors. In this case, saturation of the atmosphere follows, and then condensation of water vapors, resulting in the formation of fog, if this should happen in the air masses near the ground.

— Accumulation of water vapors in the atmosphere (through the arrival of humid air masses) without change of temperature. We have again the same results as above.

On the contrary, conditions not favoring the formation (or even the persistence) of fog, are the following.

— Rise of air temperature while the amount of water vapors remains the same. Air temperature getting away from dew point: we have as a rule dispersion of fog and increase of the visibily.

— Great wind velocities, cause mixing of air masses, rendering them homogeneous and eventually remove water condensations, and as a result do not allow the formation of fog, and even disperse it.

Finally we mention the case of recurrence of the phenomenon of fog: In cases when there is really no shifting of the air mass, the fog that has initially formed during the night and subsequently dispersed in the day (because of increasing temperatures), results in increasing the water vapor content of the air near the earth's surface (rise of the dew - point) and during the following night the thermal radiation enables the reccurence of fog.

Following the above, we have drown T a b l e I V, containing mean values of the diurnal and nocturnal twelve - hours and their difference, for each weather - type as an average of the eight - month period, and also the corresponding mean values of the eight - month period as an average of the whole eleven - year period examined, for air temperature, dew - point, and relative humidity, and for cases recorded at 0600 GMT, with visibility of $\leq$ 2000 m.

Below we examine the behaviour of the following meteorological parameters: temperature, dew - point, relative humidity, and wind, in the formation of fogs in the area of Thessaloniki.

(a) A i r t e m p e r a t u r e. In cases of fog, with all weather - types, the mean air temperature of the nocturnal twelve - hours is smaller

TABLE IV

		I	II	III	IV	V	VI	VII	VIII	IX	Xa	Xb	XI	XII	8-month period
T° C	N	5,6	4,9	8,6	9,2	6,2	8,8	8,3	8,7	8,5	8,0	9,7	7,8	9,3	10,6
	D	8,7	9,4	11,7	14,1	11,8	11,7	10,9	12,6	12,3	12,8	13,1	12,0	12,1	13,8
	D - N	3,1	4,5	3,1	4,9	5,6	2,9	2,6	3,9	3,8	4,8	3,4	4,2	2,8	3,2
Td°C	N	3,7	2,5	7,2	7,1	4,6	7,6	6,9	7,0	6,7	4,8	7,9	5,5	8,2	7,6
	D	4,9	4,8	9,1	9,2	6,1	9,3	7,4	8,8	8,0	8,7	7,4	6,0	9,7	8,4
	D - N	1,2	2,3	1,9	2,1	1,5	1,7	0,5	1,8	1,3	3,9	—0,5	0,5	1,5	0,8
Rh%	N	87,4	84,6	90,7	86,7	85,3	93,0	91,6	89,0	89,0	84,0	88,7	85,3	92,7	81,5
	D	77,7	73,3	83,9	72,8	68,3	85,9	81,1	78,0	75,7	81,1	70,2	67,7	85,4	70,3
	N - D	9,7	11,3	6,8	13,9	17,0	7,1	10,5	11,0	13,3	2,9	18,5	17,6	7,3	11,2

than the mean air temperature of the same twelve - hours for the whole eight - month period: 10,6° C. This is due to the fact that the largest percentage of the total of cases is due either to the nocturnal thermal radiation (ground fogs), or to frontal disturbances (frontal fogs) which disturbances caused the arrival of a colder air mass. This greater decrease of the mean nocturnal air temperature as to the corresponding mean temperature of the eight - month period, favors the saturation of air masses near the earth's surface, resulting in the condensation of water vapors and the formation of fog.

— The difference between mean air - temperature of the diurnal and the nocturnal twelve - honrs for weather - types of the radiation group, is comparatively great (of the order of 4° C), regardless of the stationary air mass being (according to its origin) cold or warm. This difference for all weather types of the above group, is >3,2° C, that is the difference of mean monthly air temperatures of the diurnal and nocturnal twelve - hours of the whole eight - month period. This is due to the clear sky that goes with weather - types of the above mentioned group, which clear sky during the night causes an intense thermal radiation (drop of temperature), and during the day increases the temperature hecause of the sunshine. Weather - types II and IV of the above mentioned group, have temperature differences Td - Tn respectively: 4,5° C and 4,9° C, of these two, weather - type II has a mean temperature for the diurnal twelve - hours of 9,4° C, while weather - type IV has a corresponding temperature of 14,1° C. This is due to the fact that weather - type II is a high - pressure system coming from the north, while weather - type IV is also a high - pressure system but coming from the warm continent of Africa.

— Cases of frontal fogs (almost with all weather - types) have a difference between mean temperatures of the diurnal and nocturnal twelve - hours, smaller than the corresponding difference of the eight - month-period (by 3,2° C). This is due to the fact that cloud - conditions (cloudiness) — more or less heavy — that go with weather - types of this group, do not allow a further decrease of temperature during the nocturnal twelve - hours, while they withhold its increase during the diurnal twelve - hours.

(b) Relative Humidity, and Dew - point. As it would be expected, all weather - types show a mean relative humidity for the nocturnal twelve - hours, larger than the corresponding relative humidity of the eight - month period (81,5 %). The differences between mean relative humidities of nocturnal and diurnal twelve - hours, for the various weather - types, have as follows: for the radiation group ⩾ 11,2 %

T A B L E V

BEAUFORT WIND - FORCE SCALE

Month	0600 GMT						1200 GMT			
	0	1	2	3	4	Total	0	1	2	Total
S	6	3	2			11				0
O	18	7				25		1		1
N	35	25				60	6	4		10
D	82	54	1			137	28	6	1	35
J	78	58	2	1		139	21	17	1	39
F	76	16		2	1	95	10	4	1	15
M	47	21	1	1		70		2		2
A	12	3				15		1		1
Total	354	187	6	4	1	552	65	35	3	103
	64,1	33,9	1,1	0,7	0,2		63,1	34,0	2,9	
%	98,0			2,0		100,0	97,1		2,9	100,0

(corresponding difference of the eight - month period); for the warm invasion group $< 11,2$ % (with the exception of weather - type Xa, where we have Rhn - Rhd $= 2,9$ %). This is explained for the radiation group, by the fact that with these weather - types the sunshine is at its maximum, while with the warm invasions' group it is extremely small or null. Thus, we observe for relative humidity (as it would be expected) the contrary of what we have observed for temperature.

Regarding the dew - point of the nocturnal twelve - hours, we observe that for all weather - types the difference between mean values of dew - point and air temperature is $\leqq 2,5°$ C, a fact that, as known, entails the condensation of water vapors and formation of fog.

(c) Wind. In Table V we give the frequency of wind velocities (in the Beaufort wind - scale) per month (at 0600 GMT and 1200 GMT), for cases of low visibility of $\leqq$ 2000 m.

— Out of the total of cases due to ≡ or ≡ + other phenomena that have been recorded at 0600 GMT, only 11 cases (2,0 %) during the whole 11 - year period show wind velocities of 2, 3 or 4 degrees of the Beaufort scale. All other cases (98,0 %) had wind velocities of 0 or 1 Beaufort force, that is calm or light air. This fact confirms the above mentioned, that great wind velocities consist an unfavorable factor for the formation or even the conservation of fog.

— The same applies for cases observed at 1200 GMT. As a matter of fact, out of 103 recorded cases with visibility $\leqq$ 2000 m., due to ≡ or ≡ + other phenomena, only 3 cases (2,9 %) show wind velocities of 2 Beaufort force, while the remaining 100 (97,1 %) had calm or light wind.

— We observe moreover that, cases recorded at 1200 GMT show smaller wind velocities, than the ones recorded at 0600 GMT. This we explain as follows: During the nocturnal twelve - hours, air temperatures are, as a rule, smaller than those of the diurnal twelve - hours. Thus, at 1200 GMT the wind blowing is assisted by the already increased temperatures and it is not necessary to reach high velocities in order to prevent the formation, or even disperse the already existing fog.

Conclusions.

1. The principal cause of the formation of fog during the cold season, in the area examined, is the increased at this season activity of atmospheric disturbances, especially along the Mediterranean - Polar front. In this way we have frontal fogs which cover 49,8 % of the total number of fogs recorded during the period examined (22,2 % from warm fronts and 27,6 % from cold fronts).

The mechanism of these fogs is almost the same, whether it is about warm - front fogs or cold - front ones, that is all these fogs are due to saturation of the atmosphere.

2. Another cause of fog formation in this area, is the thermal radiation of the ground at night. We thus have the formation of radiation fogs, which cover 42,2 % of the total of fogs recorded.

3. A very small percentage (7,1 %) is due to the invasion of warm air masses, that is warmer than the one already existing in this area.

4. Extremely rare are cases of fog due to cold invasions (steam - fog) caused by extremely heavy weather conditions.

5. Finally, with weather - type XI, we not only have no fog, but on the contrary we have dispersion of any already existing fog.

6. Low visibilities due to precipitation only without any fog, have been recorded in this area only during the October - March period. This means that, during the summer rains no reduction of visibility took place, such as specified at the beginning of this paper.

A few cases of low visibility in the summer season, have been recorded during the first 5′ or 10′ of strong rainfalls (showers), and they were due to the evaporation of raindrops upon touching the warm ground surface, but, as already mentioned, these cases also did'nt fill the requirements laid at the beginning of this paper, neather from the duration point - of - view (5′ or 10′), nor from the extent of the area covered ($< 20°$).

7. The mean montly number of low visibilities, regardless of cause, show a tendency to increase from September till January, and thence to decrease till the month of April. Thus the frequency courve of low visibilities is opposite to that of air temperatures, and coincides with that of relative humidity.

8. During cases of low visibility due to fog or fog and other phenomena, wind velocities have been null or very small.

9. Based upon the above mentioned data, it is possible, with the aid of weather - types, to forecast, within certain limits, the formation of fog in the area of Thessaloniki.

We give herewith Table VI, containing weather - types that have prevailed in the examined area during the 1952 - 1962 period, and the recorded cases of low visibility of ≤ 2000 m., due to $\equiv$ or $\equiv +$ other phenomena, with each weather - type.

This Table is divided in two periods: (a) The whole eight - month period (September - April) and (b) the purely winter - trimester (December - February).

TABLE VI

		I	II	III	IV	V	VI	VII	VIII	IX	Xa	Xb	XI	XII	Total
S - A	W.T.	779	378	66	84	20	291	283	147	216	26	137	91	147	2665
	Cases	96	100	38	23	3	71	46	52	45	8	11	3	56	552
	Probability	0,1	0,3	0,6	0,3	0,15	0,2	0,2	0,4	0,2	0,3	0,08	0,03	0,4	0,2
D - F	W.T.	261	159	34	25	3	117	109	79	51	15	48	40	52	993
	Cases	61	69	27	12	3	52	32	36	25	6	5	2	41	371
	Probability	0,2	0,4	0,8	0,5	1,0	0,4	0,3	0,5	0,5	0,4	0,1	0,05	0,8	0,4

According to this Table, weather - types III and XII have the greatest probability for the formation of fog. This means that, with southern component currents (characters of warm and humid air masses, arriving on the coast of the North Aegean Sea), we have greater probabilities of fog formation in this area.

The most unfavorable weather - type for the formation of fog, but also for the conservation of any already existing fog, is weather - type XI, which is well known to the inhabitants of the Axios valley for its intensity and its dryness.

About weather - type V we cannot express any certain opinion, because of its being so very rare.

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Numerical data employed in this paper, have been taken from the following publications and observational records:

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2. Annuaire de l'Institut Météorologique et Climatologique de l'Université de Thessaloniki. No. 19 - 26 (1952 - 1959), Thessaloniki.
3. Observational records of the Meteorological Observatory of the University of Thessaloniki, 1952 - 1962.