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NATURE OF THE DIURNAL VARIATION OF ATMOSPHERIC PRESSURE IN THESSALONIKI

By

T. J. MAKROYANNIS

(Institute of Meteorology and Climatology, Aristotelian University of Thessaloniki)
(Introdueed by Prof. G. C. Livadas)

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Abstract: *The nature of the diurnal variation of Atmospheric pressure in Thessaloniki is examined for the 1931-39 and 1947-70 period.*

The resulting hourty mean values indicate that:

a. Atmospheric pressure, as an average for the 24-hours, has a double fluctuation, with a primary maximum around 10:00 hours, and a primary minimum around 17:00, while the secondary maximum and minimum occur around 24:00 and 04:00 hours respectively.

b. In the months of December and January a tertiary Rykatchef - fluctuation appears also, whose range is 0.02 mm Hg for Deccmber and 0.01 mm Hg for January, occuring between 01:00 - 03:00 hours in both months.

The Harmonic Analysis-four harmonic terms - of the above hourly values, for cach month, gave thc following results:

a. The first harmonic - 24-hours componcnt - has relatively high values in the summer and relatively small ones in winter, opposing the average annual variation of atmospheric pressure in Thessaloniki; however this scems to contribute positively to the occurencc of the primary minimum around 17:00 hours.

b. The second harmonic term - 12-hour component - should contribute considerably to the development of the primary maximum and the secondary minimum of the diurnal variation. Thc annual mean value of the amplitude of this component coincides with Simpson's views (equatorial componcnt).

c. The third harmonic term - 8-hour component - has relatively higher values in winter than in summer. This contributes also to thc secondary maximum.

d. The contribution of the fourth harmonic term - 6-hour component - is generally insignificant.

Introduction

The need for systematic study of the diurnal variation of atmospheric pressure, resulted generally from the use of barometric tendencies in pressure-change charts for forecasting purposes prevailing pressure systems.

In the present paper we study the nature of the diurnal variation

of atmospheric pressure in Thessaloniki, from the viewpoint of hourly values and their mathematical expressions.

The first who examined atmospheric pressure in Thessaloniki was ALEXANDROU [2] who of course gives tables of hourly values but they only cover the 1930 - 1937 period.

Another general study on atmospheric pressure in Thessaloniki has been previously published (LIVADAS - MAKROYANNIS [9]) in which hourly values of the 1931 - 1939 and 1947 - 1970 period were examined.

In the past AEGINITIS [1], FINDIKLIS [14] and MARIOLOPOULOS [12] have studied the subject of atmospheric pressure in Athens based upon measurements of the 1894 - 1903 period the former, and 1904 - 1929 period the other two.

MATERIAL AND PROCESS

The basic material of this study, consists in the hourly values of atmospheric pressure taken from the recording of an uneroid barograph combined with readings of a mercury barometer (both manufactured by R. Fuess) for 33 years in all, that is 1930 to 1939 and 1947 to 1970.

These instruments have fuctioned in the old and the new site of the weather station of the Institute of Meteorology and Climatology of the Aristotelian University of Thessaloniki. (1930 - 1958: Hz = 46.35 m, 1959 - 1970: Hz = 30.78 m) (Livadas [10]).

All these values have been reduced to O°C and M.S.L., through a special program for processing the above data in the electronic computer (I.B.M. 1620/II) of the Aristotelian University (MAKROYANNIS & ARSENI - PAPADIMITRIOU [11]).

From *Tables* I and II and *Graph I* we draw the following conclusions.

a. Atmospheric pressure in Thessaloniki as an average over the whole year, has a *double fluctuation* in 24-hours (Table I & Graph I): The primary maximum (max I) occurs around 10 : 00 and the secondary one (max 2) around 24 : 00 ; while the primary minimum (min I) occurs around 17 : 00 and the secondary minimum (min 2) around 04 : 00 (l. t.) (Table II, Graph I, year-curve).

b. The deviation from the mean-time of (max 1), (max 2), (min 1) (min 2) is for every month of the year $\pm$ 1 or $\pm$2 hours (Table II).

c. The daily range of (max 1-min 1) is larger in summer and smaller in winter. The opposite exactly happens for the nightly range (max 2-min 2) (Table II).

d. The mean value of the daily and nightly range is almost steady the whole year through. (Table II).

TABLE I

Hourly mean values of Atmospheric pressure (M.S.L.) in Thessaloniki (period 1931-39 &1947-70). (in mm Hg)

	1	2	3	4	5	6	7	8	9	10	11	12
J	763.74	763.71	763.72	763.60	763.48	763.48	763.64	763.86	764.06	764.19	764.17	763.91
F	762.58	762.53	762.46	762.33	762.31	762.34	762.47	762.78	762.90	762.96	762.97	762.81
M	762.51	762.46	762.31	762.19	762.20	762.28	762.44	762.68	762.81	762.86	762.79	762.63
A	761.02	760.89	760.77	760.71	760.72	760.86	761.09	761.24	761.31	761.36	761.27	761.06
M	760.64	760.54	760.48	760.41	760.48	760.67	760.81	760.90	760.87	760.87	760.84	760.70
J	760.54	760.46	760.37	760.35	760.45	760.60	760.77	760.95	760.95	760.90	760.81	760.65
J	759.84	759.79	759.72	759.71	759.79	759.95	760.13	760.29	760.29	760.21	760.09	759.91
A	760.09	760.04	760.00	759.97	760.04	760.21	760.41	760.58	760.64	760.62	760.50	760.27
S	762.63	762.56	762.48	762.43	762.46	762.58	762.80	762.97	763.15	763.21	763.12	762.92
O	764.17	764.11	763.98	763.92	763.95	764.00	764.15	764.46	764.60	764.62	764.54	764.34
N	764.19	764.14	764.06	763.96	763.95	763.98	764.12	764.40	764.57	764.65	764.61	764.81
D	763 37	763 34	763.36	763.23	763.14	763.15	763.29	763.50	763.67	763.82	763.79	763.46
Mean	762.11	762.04	761.97	761.90	761.91	762.00	762.17	762.38	762.48	762.52	762.45	762.24

	13	14	15	16	17	18	19	20	21	22	23	24
J	763.36	763.31	763.22	763.19	763.21	763.22	763.47	763.60	763.65	763.97	764.05	764.07
F	762.44	762.08	761.84	761.77	761.78	761.91	762.15	762.32	762.44	762.54	762.56	762.59
M	762.30	762.00	761.73	761.57	761.52	761.62	761.84	762.10	762.32	762.43	762.48	762.48
A	760.82	760.58	760.24	760.02	759.97	760.01	760.17	760.50	760.83	760.94	761.00	761.04
M	760.50	760.29	759.99	759.81	759.73	759.73	759.92	760.14	760.48	760.65	760.70	760.71
J	760.40	760.12	759.85	759.66	759.53	759.54	759.70	759.90	760.26	760.47	760.55	760.57
J	759.62	759.32	759.03	758.84	758.70	758.69	758.85	759.08	759.45	759.67	759.78	759.85
A	759.97	759.65	759.32	759.12	758.99	758.96	759.14	759.42	759.80	759.97	760.07	760.14
S	762.62	762.28	761.97	761.79	761.73	761.79	761.96	762.31	762.55	762.66	762.73	762.73
O	763.96	763.62	763.42	763.32	763.30	763.46	763.72	763.90	764.10	764.20	764.21	764.18
N	763.98	763.69	763.56	763.56	763.64	763.83	764.01	764.16	764.27	764.35	764.37	764.37
D	763.07	762.76	762.66	762.71	762.78	762.91	763.07	763.22	763.31	763.37	763.43	763.39
Mean	761.92	761.64	761.40	761.28	761.24	761.30	761.50	761.72	761.95	762.10	762.16	762.17

TABLE II

	time of max.$_1$	time of min.$_1$	time of max.$_2$	time of min.$_2$	max.$_1$ values	min.$_1$ values	max.$_2$ values	min.$_2$ values	max.$_1$ -min.$_1$ a	max.$_2$- -min.$_2$ b	sum (a+b)	mean of a,b
J	10:00	16:00	24:00	05:00	64.06	63.06	63.94	63.35	1.00	0.59	1.59	0.79
F	11:00	16:00	24:00	05:00	62.84	61.64	62.46	62.18	1.20	0.28	1.48	0.74
M	10:00	17:00	01:00	04:00	62.73	61.39	62.38	62.06	1.34	0.32	1.66	0.83
A	10:00	17:00	24:00	04:00	61.23	59.85	60.91	60.58	1.39	0.33	1.72	0.84
M	08:00	17:00	24:00	04:00	60.74	59.61	60.58	60.29	1.14	0.30	1.44	0.72
J	08:00 09:00	17:00	24:00	04:00	60.82	59.41	60.44	60.23	1.42	0.22	1.64	0.82
J	08:00 09:00	18:00	24:00	04:00	60.16	58.57	59.73	59.59	1.60	0.14	1.74	0.87
A	09:00	18:00	24:00	04:00	60.51	58.84	60.02	59.85	1.68	0.17	1.85	0.92
S	10:00	17:00	24:00	04:00	63.08	61.60	62.60	62.30	1.48	0.30	1.78	0.89
O	10:00	17:00	23:00	04:00	64.49	63.17	64.08	63.79	1.32	0.29	1.61	0.80
N	10:00	15:00 16:00	23:00 24:00	05:00	64.52	63.43	64.24	63.82	1.09	0.42	1.51	0.75
D	10:00	15:00	23:00	05:00	63.69	62.53	63.30	63.01	1.16	0.29	1.45	0.72
Mean	10:00	17:00	24:00	04:00	62.52	61.24	62.17	61.90	1.28	0.27	1.55	0.78

G R A P H (I)

ACTUAL DIURNAL PRESSURE VARIATION
AT THESSALONIKI GREECE

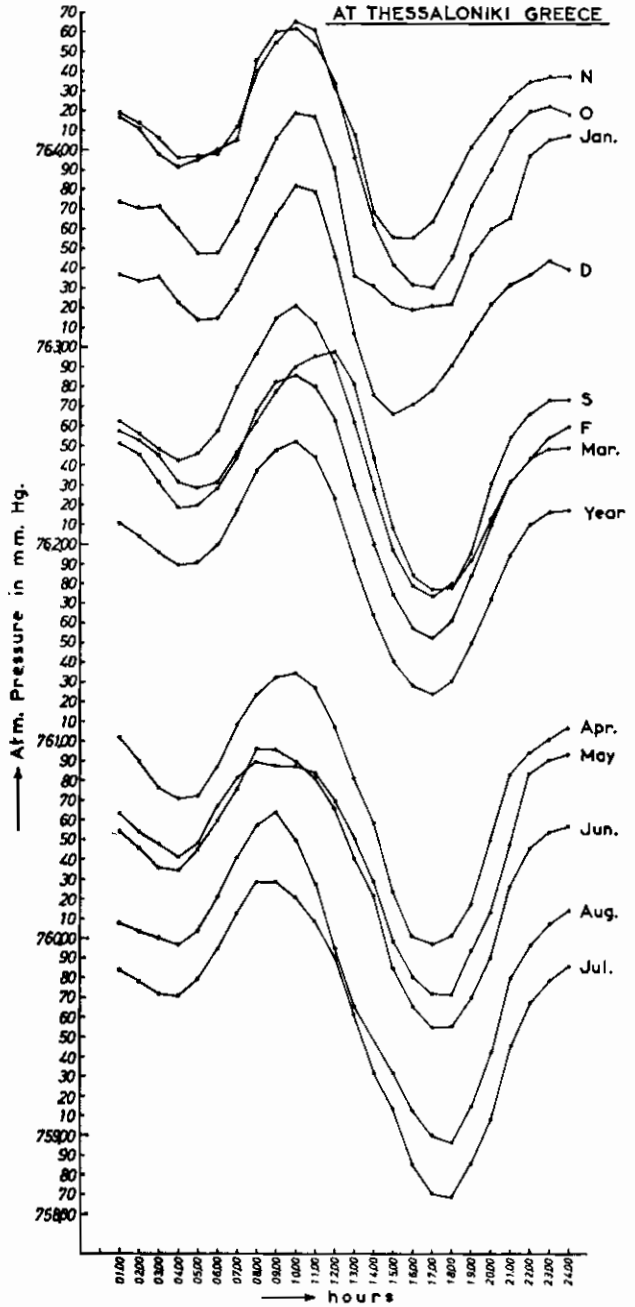


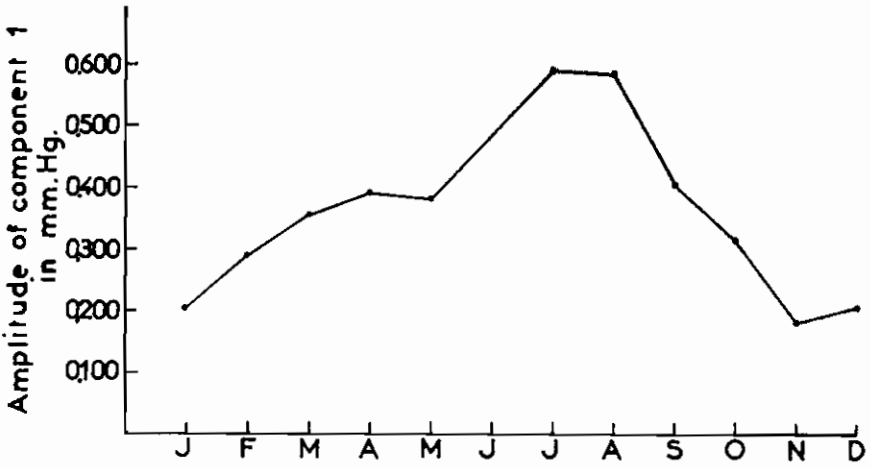
TABLE IV

Harmonic analysis of diurnal variation of pressure (M.S.L.) at Thessaloniki Greeee.

	mean pressure mm Hg	1st harmonic a_1 mmHg	t_1	A_1	2nd harmonic a_2 mmHg	t_2	A_2	3rd harmonic a_3 mm Hg	t_3	A_3	4th harmonic a_4 mm Hg	t_4	A_4	t_{1min}	t_{2min}
J	763.66	0.204	$3^h50'$	32°.32	0.363	$9^h29'$	165°.43	0.087	$0^h55'$	48°.28	0.085	$3^h23'$	247°.00	$15^h51'$	$3^h29'$
F	762.41	0.290	$5^h16'$	11°.09	0.376	$9^h30'$	164°.98	0.104	$1^h50'$	7°.07	0.009	$0^h37'$	52°.43	$17^h15'$	$3^h30'$
M	762.27	0.356	$5^h6'$	13° 44	0 402	$9^h37'$	161° 52	0.049	$1^h53'$	4°.70	0.030	$1^h16'$	13°.46	$17^h06'$	$3^h37'$
A	760.76	0.392	$5^h10'$	12°.36	0.424	$9^h41'$	159°.21	0.007	$6^h7'$	174°.76	0.045	$1^h29'$	0°.52	$17^h11'$	$3^h40'$
M	760.45	0.385	$5^h00'$	14°.88	0.337	$9^h38'$	160°.85	0.069	$5^h18'$	211°.25	0.018	$0^h31'$	58°.70	$17^h00'$	$3^h38'$
J	760.34	0.488	$5^h24'$	9°.00	0.359	$9^h37'$	161°.51	0.058	$5^h49'$	187°.97	0.012	$1^h14'$	16°11	$17^h24'$	$3^h37'$
J	759.60	0.591	$5^h17'$	10°.69	0.359	$9^h38'$	160°.78	0.054	$5^h59'$	180°.76	0.015	$1^h22'$	7°.83	$17^h17'$	$3^h38'$
A	759.91	0.586	$5^h32'$	7°.00	0.402	$9^h37'$	161°.57	0.037	$5^h41'$	194°.32	0.021	$1^h56'$	333°.80	$17^h32'$	$3^h37'$
S	762.51	0.401	$5^h43'$	4°.32	0.435	$9^h31'$	164°.21	0.024	$3^h1'$	314°.51	0.017	$2^h00'$	329°.99	$17^h43'$	$3^h31'$
O	764.00	0.327	$5^h5'$	13°.60	0.408	$9^h17'$	171°.41	0.073	$1^h44'$	11°.79	0.016	$1^h52'$	337°.58	$17^h05'$	$3^h17'$
N	764.11	0.184	$4^h14'$	26°.34	0.378	$9^h6'$	176°.90	0.104	$1^h25'$	26°.21	0.028	$3^h31'$	238°.37	$16^h16'$	$3^h06'$
D	763.24	0.206	$5^h45'$	3°.71	0.303	$9^h40'$	159°.68	0.076	$2^h5'$	355°.76	0.055	$1^h33'$	357°.00	$17^h45'$	$3^h40'$
Year	761.94	0.368	$5^h12'$	12°.72	0.378	$9^h29'$	165°.43	0.026	$2^h25'$	21°.00	0.013	$2^h25'$	305°.19		

a_1, a_2, a_3, a_4 = The amplitude of 1st, 2nd, 3rd, 4th harmonic.
A_1, A_2, A_3, A_4 = Phase angle of 1st, 2nd, 3rd, 4th harmonic
t_1, t_2, t_3, t_4 = Time of maximum of 1st, 2nd, 3rd, 4th harmonic.
t_{1min}, t_{2min} = Time of minimum of 1st, 2nd harmonic.

Variation of amplitude (a_1), over the year of whole, follows a rather definite pattern (Graph II).



G R A P H (II)

The relatively large summer values and the rather low winter values, oppose the annual mean variations of atmospheric pressure in Thessaloniki (Table IV, column 1 and Livadas - Makroyannis [9]).

Consequently it can assumed that the first component does not contribute much to the pattern of annual variation of pressure in the area examined.

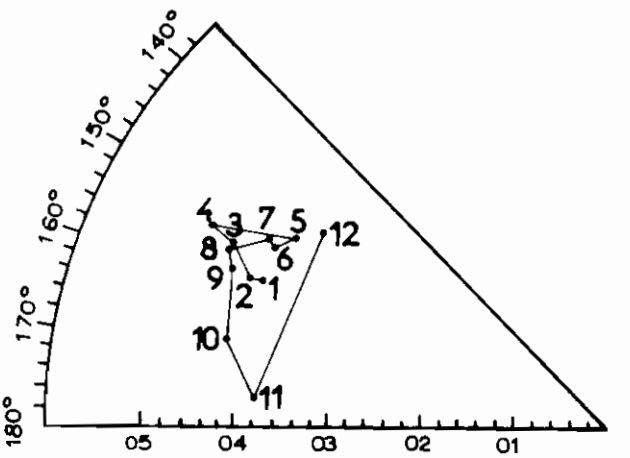
The time (t_1) of maxima of amplitudes (a_1) of the component 1 (defined by : s i n $(1\ 5\ t_1 + A_1) = 1$) is constant 05 : 00 (l.t.) during the whole year, except for January (03 : 00) and November (04 : 00 l.t.).

The time of minima (t_{1min}) of amplitudes (a_1) of this some component is also constant 17 : 00 (Table IV). Consequently the first harmonic contribute considerably to the formation of the primary minimum. (min I).

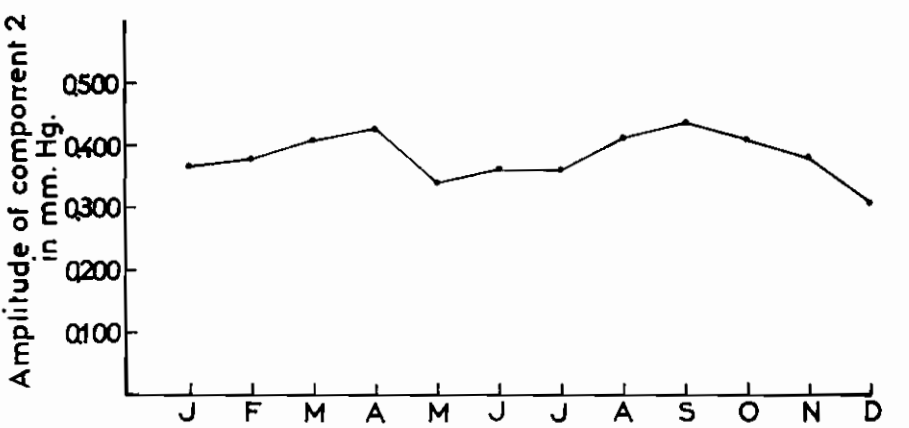
12-hour variation (component 2)

The semi-diurnal variation is believed to be the effect of a world-wide oscillation. This in fact is the most important variation and has drawn the attention of many researchers in the past.

Simpson [13] proposed that its contribution to the diurnal variation



GRAPH (III)



GRAPH (IV)

of pressure at any place could be broken down into equatorial and Polar components, defined by:

-equatorial component $(a_2) = 1.249 \cos^3\varphi \sin (30t + 154^\circ)$ mb

-polar component $(a_2) = 0.183 \left(\sin^2\varphi - \frac{1}{3}\right) \sin (30t + 105^\circ - 2\lambda)$ mb

where φ = latitude and λ = longitude

Simpson's equatorial component for Thessaloniki ($\varphi = 40^\circ 37'$) is $a_2 = 0.545$ mb, this value being in absolute agreement with that found in practice, that is : $a_2 = 0.378$ mm Hg or

$$a_2 = 0.540 \text{ mb (Table III, year).}$$

The phase angle of 165° is also in quite close agreement.

The polar component for the same area ($\lambda = 22^\circ 57'$ E) is $a_2 = 0.0165 \sin (30t + 59^\circ)$ that is rather negligible.

Graphs III and IV show that there is appreciable variation in the amplitude of component 2 with equally high values in spring and autumn and rather low-values in early summer.

The time (t_2) of maxima of amplitudes (a_2) is the same (around 09 : 00 - 09 : 30 l.t.) throughout the year. (Table IV). Consequently, it can be said that the second harmonic component contributes mainly to the primary maximum (max 1) accuring around 10 : 00 (l.t.).

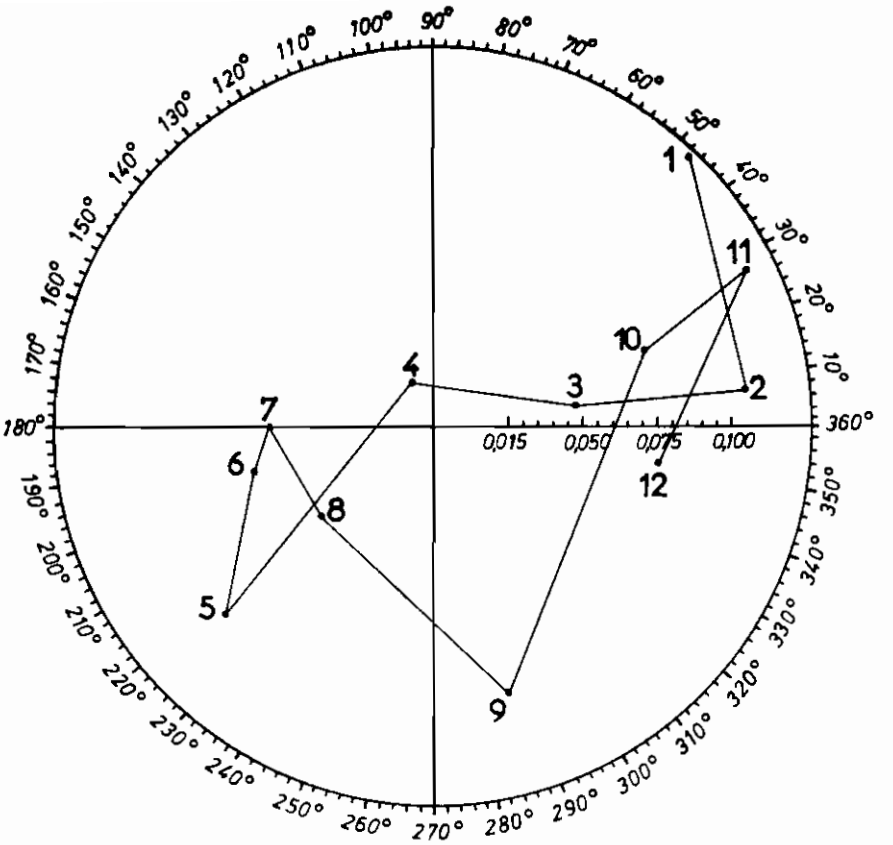
Also the time of minima (t_2 min) of (a_2) occurs as an average around 03 : 30 (l.t.) (Table IV).

Consequently the second harmonic has a definite effect on the secondary minimum (min 2) also. around 04 : 00 (l.t.).

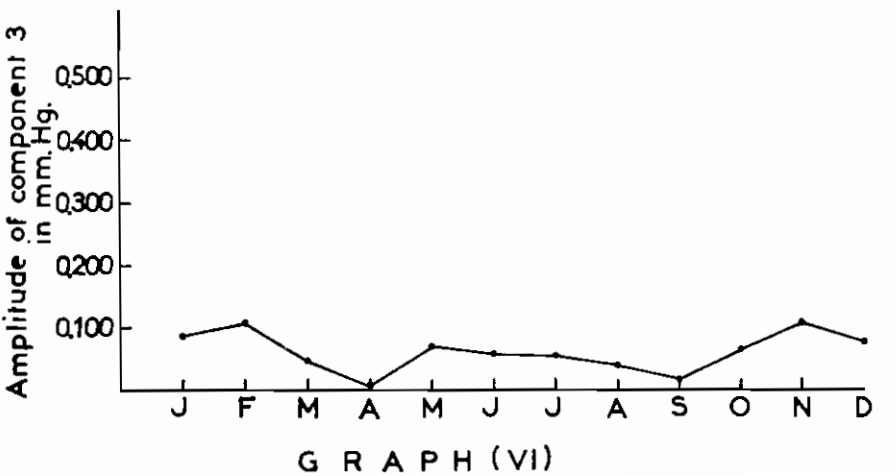
8-hour variation (component 3)

Graphs V and VI show that the variation of component 3 should constitute the main reason for higher, as an average, pressure values in winter and lower in summer, in the area examined.

The time of maxima (t_3) (Table IV) shows that the trend of winter values is the occurence of (max 2) around 24 : 00 (l.t.) while summer values result in the actually observed increase of pressure between 04 : 00 and 10 : 00 (l.t.).



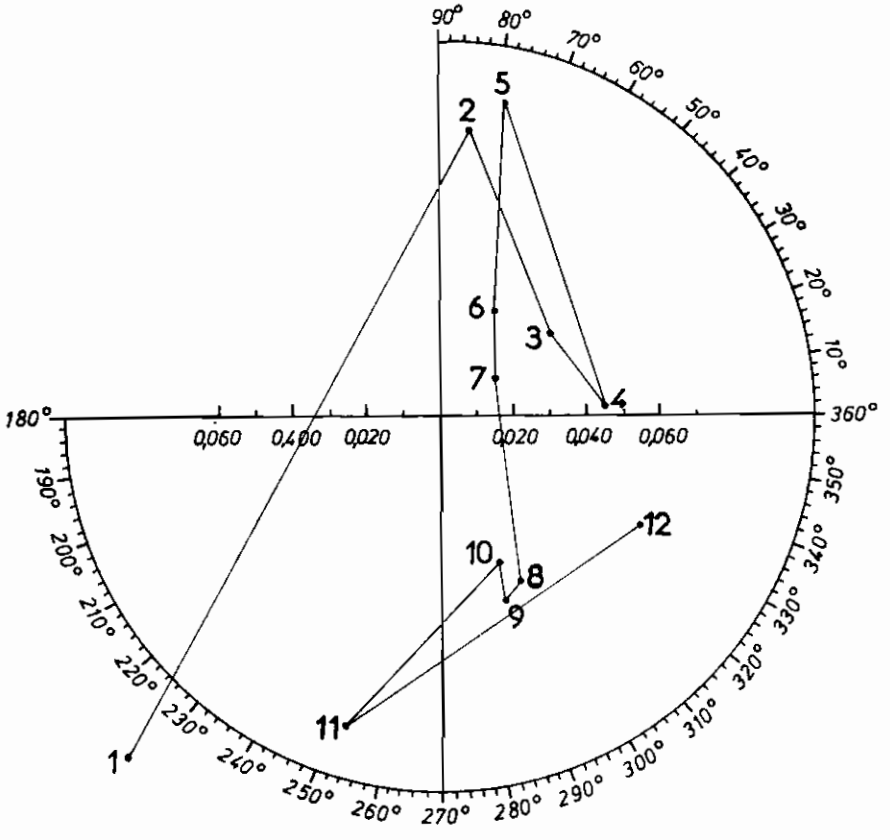
G R A P H (V)



G R A P H (VI)

6-hour variation (component 4)

Absolute values of amplitudes (a_4) as well as their variation over the year (Graphs VII and VIII) are insignificant.



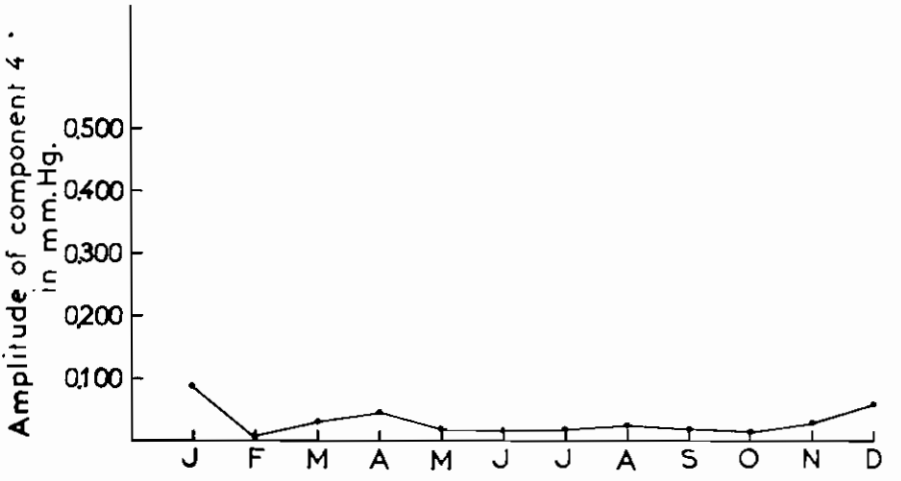
GRAPH (VII)

This and the time of maxima (a_4) show that the effect of harmonic component 4 upon the final pattern of the diurnal variation of atmospheric pressure in Thessaloniki is insignificant. This is the reason why in the present research, we have not gone further than 4 harmonic terms.

CONCLUSIONS

From all the above mentioned we draw the following conclusions:

a. The diurnal course of atmospheric pressure in Thessaloniki has a double fluctuation, except in December and January, wich also have a tertiary-Rykatchef-fluctuation, of relatively small range.



G R A P H (VIII)

b. The harmonic analysis of hourly mean values, for every month and the whole period examined, shows, that:

1. The resultant double fluctuation of this diurnal course, comes from the interference of waves of 24, 12, 8 and 6-hour period.

2. The 24-hour variation (component 1) contributes positively iu the pattern of the primary minimum (min 1) of the resultant fluctuation.

3. The 12-hour variation (component 2) also contributes to primary maximum (max 1) and the secondary minimum (min 2) of this fluctuation. There is here a coincidence with Simpson's[13] views.

4. The 8-hour variation (component 3) contributes to the relatively high winter values and lower summer values of atmospheric pressure in the area examined, and also to the secondary maximum. (max 2) of the resultant fluctuation.

5. The contributions of the 6-hour variation is overall insignificant.

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ΕΠΙ ΤΗΣ ΦΥΣΕΩΣ ΤΗΣ ΗΜΕΡΗΣΙΑΣ ΚΥΜΑΝΣΕΩΣ ΤΗΣ ΑΤΜΟΣΦΑΙΡΙΚΗΣ ΠΙΕΣΕΩΣ ΕΝ ΘΕΣΣΑΛΟΝΙΚΗ

Ὑπὸ

ΤΙΜΟΛΕΟΝΤΟΣ Ι. ΜΑΚΡΟΓΙΑΝΝΗ

(Ἐκ τοῦ Ἐργαστηρίου Μετεωρολογίας καὶ Κλιματολογίας, Ἀριστοτελείου Πανεπιστημίου Θεσσαλονίκης)

ΠΕΡΙΛΗΨΙΣ

Μελετᾶται ἡ φύσις τῆς ἡμερησίας πορείας τῆς Ἀτμοσφαιρικῆς Πιέσεως εἰς τὴν Θεσσαλονίκην - περίοδος 1931-39 καὶ 1947-70.

Αἱ εὑρεθεῖσαι μέσαι ὡριαῖαι τιμαὶ δεικνύουν ὅτι :

α. Κατὰ μέσον ὅρον, ἡ ἀτμοσφαιρικὴ πίεσις κατὰ τὴν διάρκειαν τοῦ 24ώρου, παρουσιάζει διπλῆν κύμανσιν, μὲ τὸ κύριον μέγιστον περὶ τὴν 10:00 ὥραν, τὸ κύριον ἐλάχιστον περὶ τὴν 17:00, τὸ δευτερεῦον μέγιστον περὶ τὴν 24:00 καὶ τὸ δευτερεῦον ἐλάχιστον περὶ τὴν 04:00 ὥραν.

β. Εἰς τοὺς μῆνας Δεκέμβριον καὶ Ἰανουάριον ἐμφανίζεται καὶ τριτεύουσα κύμανσις Rykatchef - εὖρους 0.02 mmHg διὰ τὸν Δεκέμβριον καὶ 0.01 mmHg διὰ τὸν Ἰανουάριον, καὶ μεταξὺ τῶν ὡρῶν 01:00 - 03:00, δι' ἀμφοτέρους τοὺς μῆνας.

Ἡ Ἁρμονικὴ Ἀνάλυσις - τέσσαρες ἁρμονικοὶ ὅροι - τῶν ὡς ἄνω ὡριαίων τιμῶν, δι' ἕκαστον μῆνα, δίδει τὰ ἑξῆς ἀποτελέσματα :

α. Ὁ πρῶτος ἁρμονικὸς ὅρος - περίοδος 24 ὡρῶν - παρουσιάζει ὑψηλὰς σχετικῶς τιμὰς κατὰ τὸ θέρος καὶ χαμηλὰς κατὰ τὸν χειμῶνα, ἤτοι ἀντίθετα μὲ τὴν κατὰ μέσον ὅρον ἐτησίαν πορείαν τῆς ἀτμοσφαιρικῆς πιέσεως εἰς τὴν Θεσσαλονίκην, ἀλλὰ φαίνεται νὰ συμβάλλῃ θετικῶς εἰς τὴν διαμόρφωσιν τοῦ κυρίου ἐλαχίστου περὶ τὴν 17:00 ὥραν.

β. Ὁ δεύτερος ἁρμονικὸς ὅρος - περίοδος 12 ὡρῶν - πρέπει νὰ συμβάλλῃ θετικῶς εἰς τὴν διαμόρφωσιν τοῦ κυρίου μεγίστου καὶ τοῦ δευτερεύοντος ἐλαχίστου τῆς ἡμερησίας κυμάνσεως. Ἡ μέση δὲ ἐτησία τιμὴ τοῦ πλάτους τοῦ ὅρου αὐτοῦ, εὑρίσκεται εἰς ἀπόλυτον συμφωνίαν μὲ τὰς ἀπόψεις τοῦ Simpson ἰσημερινὴ συνιστῶσα -.

γ. Ὁ τρίτος ἁρμονικὸς ὅρος - περίοδος 8 ὡρῶν - ἐμφανίζεται μὲ ηὐξημένας σχετικῶς τιμὰς κατὰ τὸν χειμῶνα, ἔναντι τοῦ θέρους. Συμβάλλει δὲ θετικῶς εἰς τὴν διαμόρφωσιν τοῦ δευτερεύοντος μεγίστου.

δ. Ἡ συμβολὴ δὲ γενικῶς τοῦ τετάρτου ἁρμονικοῦ ὅρου - περίοδος 6 ὡρῶν - εἶναι ἀσήμαντος.