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DIURNAL CHANGES OF THE AIR TEMPERATURE IN DIFFERENT AIR MASSES

The purpose of this paper is to define the character of air temperature changes with respect to season of the year and the occurring air mass.

Changes of air temperature within twenty four hours were studied on the basis of mean values from hourly measurements (1^h-24^h) made in the period 1956—1960 at the meteorological station Warszawa—Okęcie.

Considering mean daily amplitudes it is possible to distinguish two types of the daily course of air temperature (Fig. 1). In the cold season of the year (November-February) the daily amplitudes are small and range from 1.5 to 3.5°C. Temperature changes from one hour to next, particularly at night, are small. Large daily amplitudes are observed in the warmer season of the year (March-October) when they may range from 6.0 to 9.0°C.

In the daily temperature changes attention should be paid to the time when extreme values occur. The time of occurrence of lowest and highest temperatures was referred to the time of sunrise, sunset and sun predominance (Fig. 2a). Daily minimum values in winter are observed about 0.5—1 hour before sunrise, in summer—a dozen or so minutes after sunrise. This means that in winter the lowest temperatures are noted at about 7 a.m. whereas in summer about 4 a.m. Maximum temperatures may occur at about 1 p.m. in winter and about 3 p.m. in summer.

In order to determine the significant periodic changes of daily air temperature changes, the method of harmonic analysis was used. Each periodic curve may be presented, in an appropriate approximation, as a sum of sinusoids with various periods and amplitudes. This means that the studied periodic changes can be presented as a trigonometric sequence:

$$t_i = t_0 + t_1\sin(A_1 + \alpha) + t_2\sin(A_2 + 2\alpha) + t_3\sin(A_3 + 3\alpha) + \dots$$

where:

t_i — air temperature for i-th hour,

t_0 — average daily temperature,

$t_1, t_2, \dots A_1, A_2, \dots$ — sought constants,

$\alpha = \frac{360^\circ}{n} \cdot i$ — with n meaning the number of observation times, i — the hour for which the air temperature is sought.

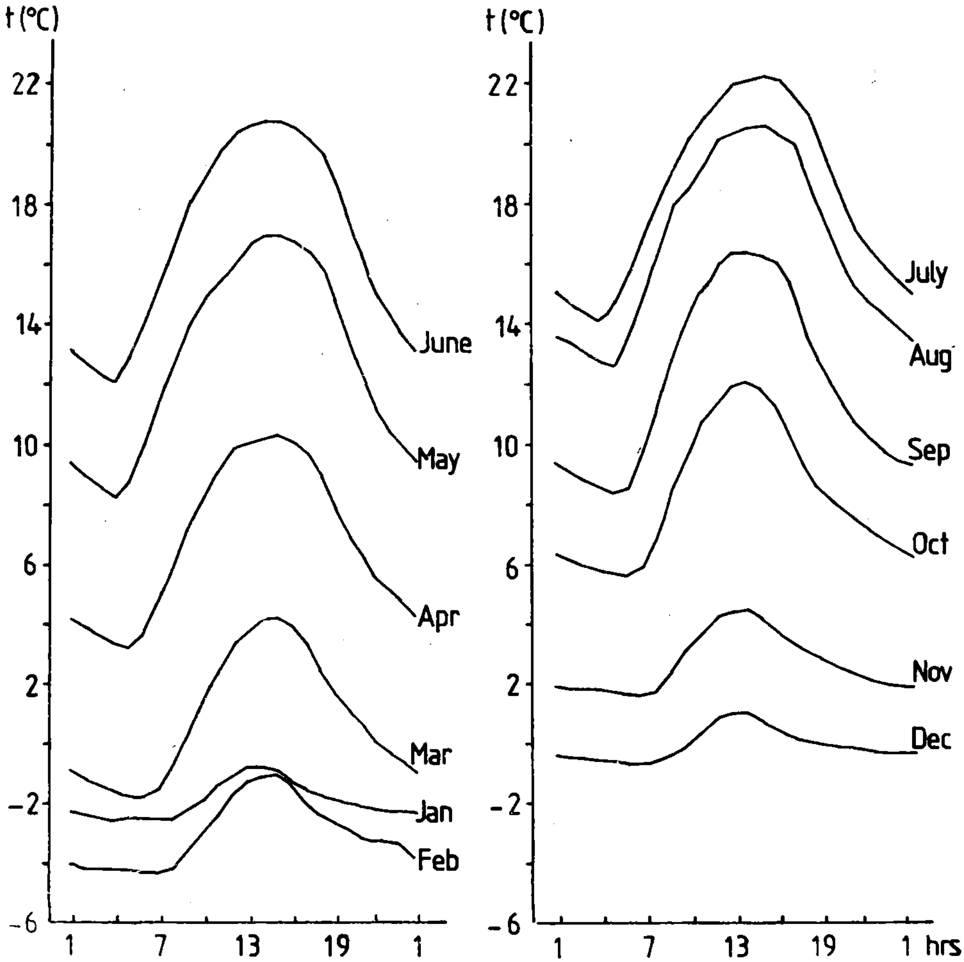

Fig. 1. Diurnal course of air temperature (Warsaw-Okęcie, 1956—1960)

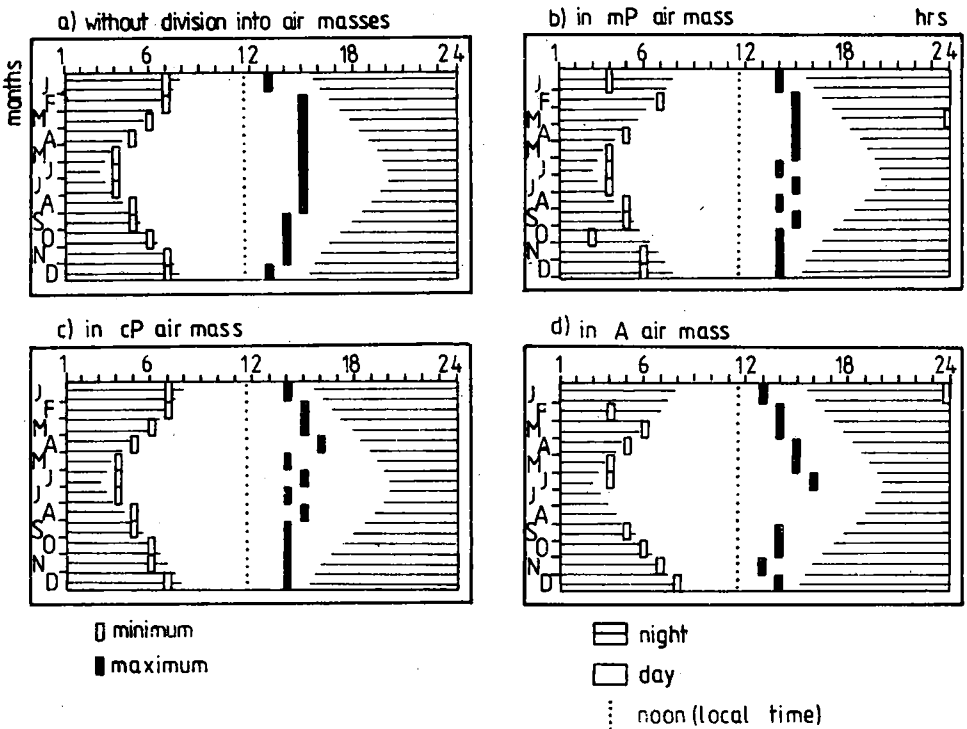

Fig. 2. Time of appearance of daily extremes of air temperature in respect of sunrise and sunset (Warsaw-Okęcie, 1956—1960)

In this paper the harmonic analysis was limited to three harmonics (Table 1a). They define theoretical air temperature changes within a day and give a picture of changeability from one hour to next. The higher the absolute values of the parameters, the higher changeability should be expected. It is much higher between March and October and lower between November and February. This confirms the distinction between the two types of daily changes.

The above analysis of diurnal changes of air temperature did not account for weather conditions. It is well known that the changes do not depend only on the daily cycle of solar radiation but also on thermal properties of the occuring air masses.

Investigating these interrelations, the geographical division of air masses was used and the following were taken into account: maritime polar (*mP*) air mass, continental polar (*cP*) air mass and artic (*A*) air mass. In further investigations tropic air mass (*T*) and artic mass in July and August were excluded due to a small number of cases in the studied five-year period. Investigating daily changes only those days were taken into account during which a given air mass occured from 0^h to 24^h, that is days with a front passing, characterized by a change in air mass, were disregarded.

Table 1

Coefficients of equations of diurnal course of the air temperature. Warsaw, 1956—1960
a. without division into air masses; b. in *mP* air mass; c. in *cP* air mass; d. in *A* air mass.

	Month	t^o	t_1	A_1	t_2	A_2	t_3	A_3
a	I	−1.9	−0.7734	62.88	0.4450	83.58	−0.1464	110.22
	II	−3.0	−1.4741	52.77	0.5415	66.18	−0.1663	37.75
	III	0.9	−4.4519	33.47	0.7148	79.83	0.0486	150.17
	IV	6.8	−4.8633	41.40	0.5151	107.73	0.3144	79.38
	V	12.9	−4.2914	68.03	0.1819	170.67	−0.5067	81.53
	VI	16.8	−4.3575	70.60	−0.2561	3.73	0.3631	95.97
	VII	18.5	−4.0462	69.40	0.1116	135.00	0.3858	95.95
	VIII	16.8	−4.0087	71.07	0.4398	104.60	0.4574	95.65
	IX	12.3	−4.1768	71.78	−0.0611	44.47	0.1843	61.22
	X	8.5	−3.0132	69.43	0.9450	92.52	−0.0831	130.90
	XI	2.9	−1.2563	68.57	0.5990	54.22	−0.1330	135.45
	XII	−0.1	−0.6394	67.20	0.3483	88.98	−0.1500	111.30
b	I	0.9	−0.7331	53.18	0.2687	78.35	0.0892	84.65
	II	1.4	−1.2635	51.65	0.7254	81.38	−0.1369	56.98
	III	3.9	−1.9086	72.28	0.7009	42.58	0.9668	10.05
	IV	6.7	−2.9978	61.53	0.5370	105.68	0.3249	99.02
	V	12.5	−3.6107	69.77	0.0610	21.13	0.7640	90.70
	VI	15.9	−3.7771	69.83	0.0848	158.48	0.3094	78.60
	VII	17.2	−3.2666	75.82	0.0489	106.15	0.3710	83.18
	VIII	16.0	−3.6529	70.53	0.3335	79.75	0.4410	80.58
	IX	12.9	−3.3001	75.08	0.6330	75.40	0.3461	57.03
	X	9.4	−2.5626	70.70	0.7865	79.37	−0.0789	64.23
	XI	4.1	−1.2043	68.67	1.0682	155.65	−0.1785	126.62
	XII	2.4	−0.5725	67.20	0.3160	90.77	−0.1618	81.97
c	I	−7.0	−0.9928	60.95	0.5602	65.52	2.0373	19.40
	II	−9.8	−1.6807	50.57	0.6130	64.10	−1.2626	9.57
	III	−0.6	−2.7020	48.88	0.7892	81.35	0.0250	70.62
	IV	8.9	−4.5556	61.01	0.6448	116.40	0.4126	67.50
	V	15.0	−5.3568	69.55	0.5026	165.32	0.5401	100.85
	VI	19.0	−4.6834	66.80	−0.5844	18.22	0.5614	108.82
	VII	20.4	−5.3649	68.18	0.2415	152.18	0.4652	105.38
	VIII	18.8	−5.4161	68.22	0.8401	124.22	0.7152	125.77
	IX	13.3	−5.2783	68.43	1.1156	99.82	0.3989	97.48
	X	9.2	−4.5107	68.20	1.3757	93.47	0.3660	66.93
	XI	2.7	−1.3934	56.72	0.5401	83.53	−0.2390	138.00
	XII	−3.2	−0.8074	51.23	0.6246	148.60	−0.1424	109.95
d	I	−4.4	−0.7120	114.55	0.2507	77.33	−1.1407	11.18
	II	−3.4	−1.6707	71.18	0.4919	74.38	−0.0711	78.48
	III	−3.1	−2.1739	49.75	0.7971	71.33	0.1876	17.78
	IV	3.1	−2.2719	68.03	0.2287	64.45	0.2099	90.65
	V	8.4	−3.8134	67.63	−0.2778	22.63	0.3619	105.17
	VI	13.0	−4.1908	57.62	0.0734	162.90	0.4685	81.27
	IX	8.7	−4.2398	71.85	0.8697	93.37	0.3659	70.50
	X	6.1	−2.7590	68.20	0.7375	82.82	−0.1086	164.23
	XI	−2.3	−1.3200	89.02	0.5783	93.42	−0.1492	147.35
	XII	−1.4	−0.8329	51.18	0.6711	106.52	−0.2495	80.73

In order to study temperature changes with regard to air mass, mean values for each hour in all months of the year were calculated as previously. In result, mean daily temperature changes in various air masses were obtained (Fig. 3).

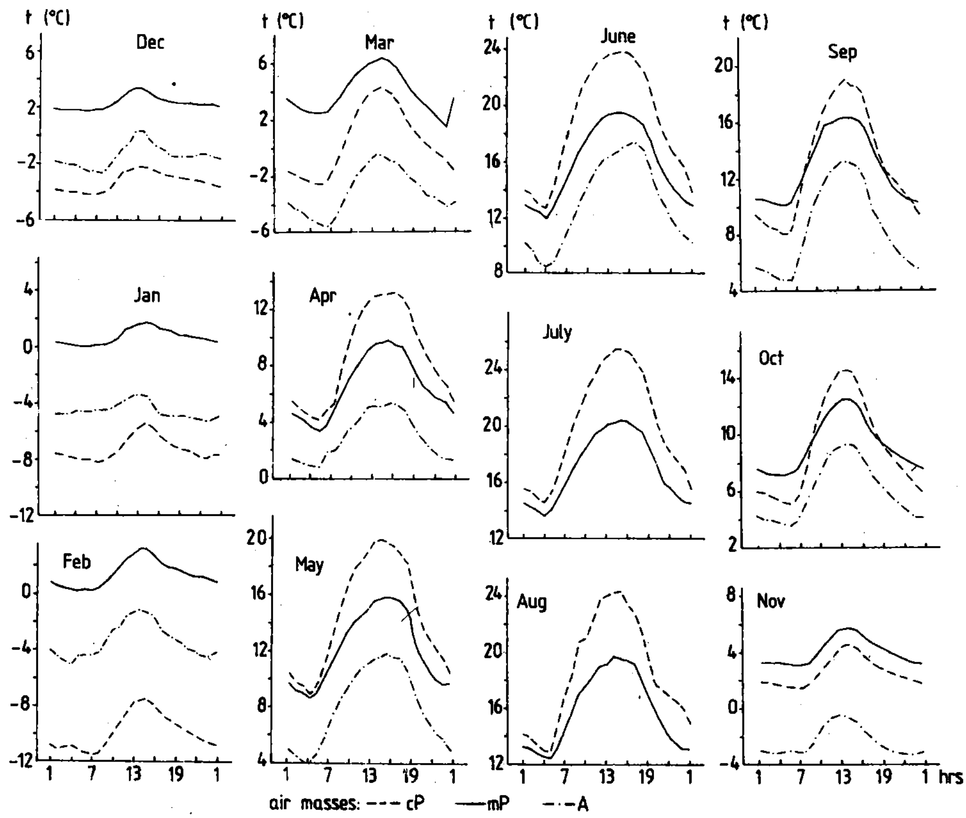

Fig. 3. Diurnal course of air temperature in different air masses (Warsaw-Okęcie, 1956—1960)

While comparing daily air temperature changes with respect to the season of the year it was found that in the cool part of the year, between November and February, lower temperatures are noted with inflow continental polar (*cP*) air mass than in the case of maritime polar (*mP*) air mass. Troughout the period under *mP* mean temperatures are always above 0°C whereas under *cP* mean temperatures may drop even to −11°C (February). Between April and August the continental polar (*cP*) air mass becomes warmer than the maritime polar (*mP*) air. Mean temperatures under *cP* may reach up to 26°C (July) whereas under *mP* they do not exceed 21°C. Daily temperature changes are specific in the autumn months (September, October). With similar mean daily temperaturtes, the continental polar air mass becomes warmer during the day whereas at night higher temperatures are registered for the maritime polar air mass. This may be connected to pressure configurations, accompanying inflows of particular air masses. The inflow of *mP* is usually connected with low pressure, with increased cloudiness, causing lowered inflow of sun radiation during the day (lower temperatures) whereas at night effective radiation is decreased (higher temperatures). The *cP* mass is usually accompanied by high pressure with little cloudiness, and sunny weather. Therefore during the day the inflow of sun radiation is increased (higher temperatures) and at night effective radiation increases (lower temperatures).

In the arctic (*A*) air mass in the winter months (December—February) mean temperature values are between the values registered for *mP* and *cP*. Flowing in from cooled artic areas over the warmer terrains of central Poland, the air undergoes a transformation, i.e. it warms up and becomes warmer than the *cP* mass coming from North-East Asia. In other months the arctic air mass is the coldest of all air masses flowing over Poland.

Mean daily temperature amplitudes also depend on the inflowing air mass. They are higher under *cP* than under *mP* throughout the year, and in summer the differences may be up to 5 C (Table 2).

The interrelation between the time of occurrence of extreme values and sunrise, sunset and sun predominance in particular air masses is illustrated in Fig. 2bcd.

Table 2

Diurnal amplitudes (°C) of the air temperatures. Warsaw, 1956—1960

Month	Withouth division into air masses	In air masses		
		mP	cP	A
I	1.9	1.7	2.8	2.2
II	3.4	3.0	4.0	4.0
III	6.1	5.0	6.8	5.1
IV	7.2	6.6	9.1	4.6
V	8.8	7.3	11.1	7.9
VI	8.8	7.6	11.2	8.8
VII	8.2	6.9	10.9	.
VIII	8.1	7.4	11.5	.
IX	8.1	6.3	11.1	8.5
X	6.5	5.4	9.6	5.8
XI	2.9	2.7	3.1	2.8
XII	1.7	1.6	1.9	3.0

The harmonic analysis for daily temperature changes in particular air masses was made in accordance with the dependences quoted above (Table 1 bcd). The coefficients (t_1, t_2, ...) determined in this way manifest a differentiation during seasons of the year and under various air masses. Under *mP* lower values of the coefficients, evidencing lower changeability from one hour to next, are observed in winter; in summer the coefficients, therefore also changeability, are higher. Under *cP* there is no such a clear distinction between the cool and warm season. The coefficients are high throughout the year which is an evidence of large temperature changes from one hour to another. Comparing the values of the coeficients under both polar masses one may notice that absolute values are higher under *cP* which produces higher temperature changes and higher daily amplitudes.

Under the arctic air mass (*A*) the coeficients of the harmonic analysis evidence smaller changes in the cool season and larger changes in the warmer season of the year.

Summarizing the above analysis, the results may be put down in the following few items:

— air temperature changes within the year depend on the inflowing air mass. In the cool season of the year the lowest temperatures are registered for the continental polar air mass, and in the warmer season—under maritime polar and artic air masses.

— temperature variations in time are largest in summer, and with respect to air masses—under *cP*.

— daily amplitudes assume the lowest values in the cool season of the year. The volume depends on the air mass, the largest being under *cP*.