MISCELLANEA GEOGRAPHICA

WARSZAWA 1986

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DEFORMATION OF FIELDS OF METEOROLOGICAL ELEMENTS UNDER THE INFLUENCE OF BUILDINGS

The Department of Climatology of the University of Warsaw has been conducting studies on urban climate for many years. The papers produced so far aimed first of all at recognizing typical, specific features of Warsaw's climate as well as discovering climate differentiation within the town. The first topic was studied on the basis of meteorological data from a long period. Those were archives of the Institute for Meteorology and Water Management. In studies concerning differentiation of climatic conditions within the town (based to a large extent on the researches of the Department of Climatology) endeavours were made to determine some features of heat island and intensity of this phenomenon during the year, depending on weather conditions. Then some characteristic features of local climate were determined in urban areas with dense building development, scarce development, greenery areas and streets with various directions. For instance, a characteristic feature of the town's fragments with dense building development, or of large complexes of parks as well as districts with quarter-like types of buildings, is a trend to occurrence of a „conserving" thermal effect. This is seen most clearly during rapid weather changes. This is connected with lowered degree of ventilation of the above-mentioned areas.

Another issue, studied only partially, is the role of urban green areas in formation of thermal-humid conditions. Studies have been conducted in greenery complexes of various sizes and types: in parks, on lawns as well as in green areas of the housing quarters. The significance of greenery has been established by showing thermal contrasts occurring between neighbouring areas: artificial and green. They have a decisive impact on the intensity of microcirculation existing between the objects.

The above-mentioned problems have been studied and published (Kaczorowska 1967; Kopacz-Lembowicz et al. 1984; Kossowska 1973, 1975; Kossowska-Cezak 1977; Stopa-Boryczka et al. 1980, 1982, 1984). Thus the stage of studies, which can be called a study of Warsaw's climate,

can be considered to have been completed. Results of the studies, with some additions, will be presented in a monography under preparation.

It is important that knowledge of the climate have more practical significance. Practicians, e.g. town planners, usually ask such questions: how will conditions change if we introduce, e.g., a certain type of buildings, that is they want to know the degree of modification to be caused by a factor. It is thus the climatologists' task to establish quantitatively the impact of factors which have a decisive impact on the specific character of urban climate, on the basis of the knowledge of physical reasons for differentiated climatological conditions in urban areas.

If dependences between some features of a heat island, e.g. its intensity and the town's size (urban area) can be determined by an equation, then such results are of practical importance. Of similar significance is to determine the threshold of wind velocity which causes the heat island to disappear as well as many other features of the local climate. The establishment of such interdependences can be referred to the entire town, treating it as a kind of a mass, as well as with reference to various types of a developed area, i.e. some characteristic fragments of the town with a certain type of buildings or streets of various orientation. These are the issues that are currently under study in the Department of Climatology. For this purpose for a few years special studies have been conducted at a dozen or so measuring posts working simultaneously,

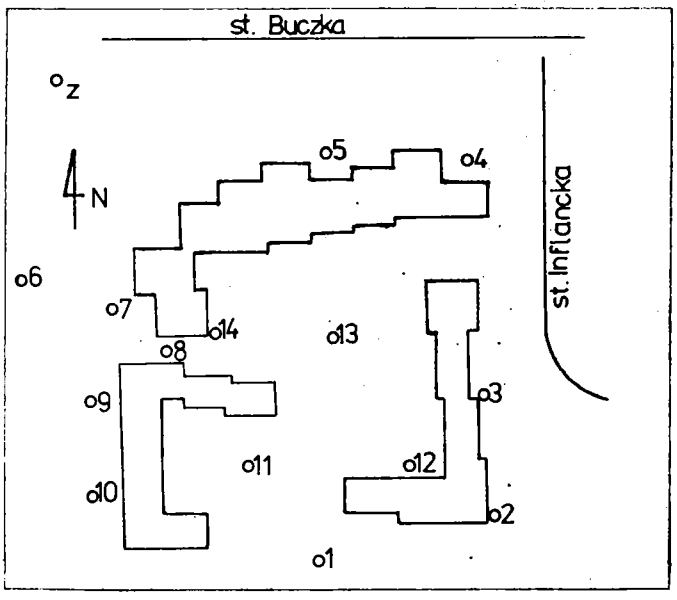

Fig. 1. Localization of the measuring points in the housing quarter Stawki

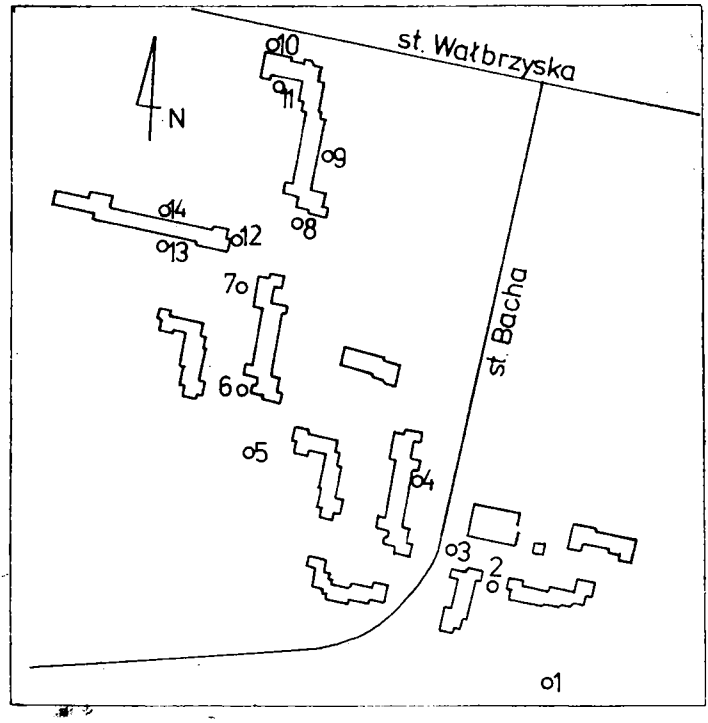

Fig. 2. Localization of the measuring points in the housing quarter Służew nad Dolinką

The outer point is located at a distance of 320 meters in the direction of SE from the point No. 1

located in housing quarters with various arrangement of buildings as well as in places of town quarter greenery.

Measurements of the main meteorological elements permit an analysis of the processes of heat exchange between a housing quarter and the surrounding, to study the rate of warming up and cooling down of individual fragments of a district, to determine the degree of deformation of the air flow field, that is those factors which have a decisive impact on ventilation of a developed area.

Deformation of fields of meteorological variables by buildings during the summer period is presented on the example of air temperature. The studies were concentrated on two housing quarters in Warsaw: Stawki — located on the northern edge of the centre, surrounded with greenery areas — and Służew nad Dolinką — located in the southern suburbs of the town. They have a similar type of buildings (blocks of flats, scarce and high), but of different size and arrangement of buildings (Fig. 1 and 2).

Table 1

Equations of regression lines of temperature differences between the housing quarter and its surroundings with respect to the air temperature outside the Quarter (t) — Stawki, July 1979; 1.5 m above ground level

Point	Morning (7–11 a.m.)		Moon (12–4 p.m.)		Evening (5–9 p.m.)	
1	$y = 2.335 - 0.106$ x	$r_{xy} = -0.47$	$y = 8.392 - 0.375$ x	$r_{xy} = -0.76$	$y = 9.110 - 0.440$ x	$r_{xy} = -0.93$
2	$y = 2.223 - 0.103$ x	$r_{xy} = -0.39$	$y = 7.193 - 0.318$ x	$r_{xy} = -0.74$	$y = 9.208 - 0.445$ x	$r_{xy} = -0.94$
3	$y = 3.249 - 0.130$ x	$r_{xy} = -0.52$	$y = 8.415 - 0.385$ x	$r_{xy} = -0.75$	$y = 7.652 - 0.373$ x	$r_{xy} = -0.92$
4	$y = 4.333 - 0.230$ x	$r_{xy} = -0.61$	$y = 1.751 - 0.138$ x	$r_{xy} = -0.24$	$y = 8.465 - 0.392$ x	$r_{xy} = -0.91$
5	$y = 7.405 - 0.441$ x	$r_{xy} = -0.93$	$y = 4.113 - 0.232$ x	$r_{xy} = -0.28$	$y = 6.867 - 0.325$ x	$r_{xy} = -0.87$
6	$y = -0.530 + 0.017$ x	$r_{xy} = 0,11$	$y = 0.524 - 0.031$ x	$r_{xy} = -0.09$	$y = -4.551 + 0.231$ x	$r_{xy} = 0.88$
7	$y = 3.358 - 0.212$ x	$r_{xy} = -0.85$	$y = -3.276 + 0.091$ x	$r_{xy} = 0.16$	$y = 8.003 - 0.378$ x	$r_{xy} = -0.92$
8	$y = 4.408 - 0.282$ x	$r_{xy} = -0.83$	$y = -4.769 + 0.164$ x	$r_{xy} = 0.45$	$y = 6.734 - 0.324$ x	$r_{xy} = -0.95$
9	$y = 3.952 - 0.253$ x	$r_{xy} = -0.88$	$y = -5.443 + 0.190$ x	$r_{xy} = 0.33$	–	–
10	$y = 0.911 - 0.061$ x	$r_{xy} = -0.29$	$y = -9.283 + 0.372$ x	$r_{xy} = 0.54$	$y = 5.768 - 0.241$ x	$r_{xy} = -0.85$
11	$y = 1.354 - 0.083$ x	$r_{xy} = -0.38$	$y = 0.626 - 0.062$ x	$r_{xy} = -0.37$	$y = 9.025 - 0.434$ x	$r_{xy} = -0.97$
12	$y = 0.522 - 0.043$ x	$r_{xy} = -0.23$	$y = -1.915 + 0.052$ x	$r_{xy} = 0.11$	$y = 4.758 - 0.232$ x	$r_{xy} = -0.62$
13	$y = -0.451 + 0.014$ x	$r_{xy} = 0.09$	$y = 4.258 - 0.198$ x	$r_{xy} = -0.45$	$y = 11.670 - 0.562$ x	$r_{xy} = -0.95$
14	$y = 6.333 - 0.366$ x	$r_{xy} = -0.91$	$y = -6.705 + 0.240$ x	$r_{xy} = 0.52$	$y = 5.667 - 0.264$ x	$r_{xy} = -0.90$

Tabela 2

Equations of regression lines of temperature differences between the housing quarter and its surroundings (y) with the Air Temperature outside the Quarter (x) — Służew nad respect to time (t) — Stawki, July 1979; 1.5 above ground level

Point	Morning (7–11 a.m.)		Noon (12–3 p.m.)		Evening (5–9 p.m.)	
1	$y = -0.928 + 0.055$ x	$r_{xy} = 0.21$	$y = 2.124 - 0.092$ x	$r_{xy} = -0.26$	$y = 7.220 - 0.333$ x	$r_{xy} = -0.96$
2	$y = -3.273 + 0.140$ x	$r_{xy} = 0.39$	$y = 26.184 - 1.139$ x	$r_{xy} = -0.81$	$y = 8.682 - 0.391$ x	$r_{xy} = -0.99$
3	$y = 0.745 - 0.034$ x	$r_{xy} = -0.12$	$y = -2.046 + 0.085$ x	$r_{xy} = 0.16$	$y = 9.478 - 0.422$ x	$r_{xy} = -0.99$
4	$y = 6.525 - 0.418$ x	$r_{xy} = -0.85$	$y = -0.009 - 0.070$ x	$r_{xy} = -0.16$	$y = 12.562 - 0.559$ x	$r_{xy} = -0.99$
5	$y = 1.708 - 0.120$ x	$r_{xy} = -0.56$	$y = 8.001 - 0.366$ x	$r_{xy} = -0.60$	$y = 5.550 - 0.247$ x	$r_{xy} = -0.98$
6	$y = 1.332 - 0.136$ x	$r_{xy} = -0.76$	$y = -3.816 + 0.128$ x	$r_{xy} = 0.28$	$y = 6.240 - 0.281$ x	$r_{xy} = -0.96$
7	$y = 4.540 - 0.328$ x	$r_{xy} = -0.85$	$y = -7.097 + 0.268$ x	$r_{xy} = 0.40$	$y = 4.831 - 0.223$ x	$r_{xy} = -0.98$
8	$y = 0.503 - 0.046$ x	$r_{xy} = -0.30$	$y = -0.933 + 0.056$ x	$r_{xy} = 0.08$	$y = 4.470 - 0.194$ x	$r_{xy} = -0.98$
9	$y = 2.472 - 0.129$ x	$r_{xy} = -0.33$	$y = 18.410 - 0.830$ x	$r_{xy} = -0.90$	$y = 9.950 - 0.452$ x	$r_{xy} = -0.98$
10	$y = 7.813 - 0.485$ x	$r_{xy} = -0.86$	$y = -8.306 + 0.298$ x	$r_{xy} = 0.54$	$y = 8.080 - 0.359$ x	$r_{xy} = -0.99$
11	$y = 4.614 - 0.329$ x	$r_{xy} = -0.80$	$y = 1.270 - 0.077$ x	$r_{xy} = -0.12$	$y = 7.280 - 0.315$ x	$r_{xy} = -0.95$
12	$y = 2.155 - 0.145$ x	$r_{xy} = -0.54$	$y = 10.175 - 0.475$ x	$r_{xy} = -0.75$	$y = 8.567 - 0.390$ x	$r_{xy} = -0.93$
13	$y = -0.930 + 0.029$ x	$r_{xy} = 0.11$	$y = 3.049 - 0.150$ x	$r_{xy} = -0.41$	$y = 9.077 - 0.401$ x	$r_{xy} = -0.97$
14	$y = 11.490 - 0.672$ x	$r_{xy} = -0.92$	$y = 2.128 - 0.157$ x	$r_{xy} = -0.50$	$y = 8.304 - 0.372$ x	$r_{xy} = -0.96$

In order to determine thermal features of the microclimate of the housing quarters, the data from measuring points located in the quarters and in their vicinity were correlated. The dependences were described by empirical formulae — equations of straight lines of regression (Tables 1 and 2), where: x — value of meteorological element outside the quarter, y — difference between the value measured in the quarter and outside it. In order to show how large is the influence of buildings on the field of air temperature, depending on the time of the day, three time intervals were distinguished: the morning 7—11 a.m., noon — 12—4 p.m. and the evening — 5—9 p.m. (of the summer time, i.e. EET), taking measurements every 1/2 hour.

There is a general regularity that regression coefficients are negative in the morning and in the evening, and around the noon they are either negative or positive. Their values obtained for various points of the housing quarters are within the ranges:

Stawki	morning	— 0.44 ÷ 0.02
	noon	— 0.38 ÷ 0.37
	evening	— 0.56 ÷ 0.23
Służew nad Dolinką	morning	— 0.67 ÷ 0.14
	noon	— 1.14 ÷ 0.30
	evening	— 0.56 ÷ — 0.19

The average fields of air temperature in the quarters are described by the equations and correlation coefficients (r_{xy}):

Stawki		
morning	$y = 2.814 - 0.163\ x$	$r_{xy} = -0.75$
noon	$y = 0.277 - 0.045\ x$	$r_{xy} = -0.15$
evening	$y = 6.363 - 0.301\ x$	$r_{xy} = -0.96$
Służew nad Dolinką		
morning	$y = 2.769 - 0.187\ x$	$r_{xy} = -0.70$
noon	$y = 3.509 - 0.180\ x$	$r_{xy} = -0.46$
evening	$y = 7.878 - 0.353\ x$	$r_{xy} = -0.99$

In the morning it is cooler within the housing quarters than outside of them, thus negative values of regression coefficients point to intensification of temperature differences between the quarter and its surrounding along with temperature growth; in both housing quarters the temperature growth is by about 0.2°C/°C lower than in the surrounding area. During the day, along with warming up of the air, at the small housing quarter of Stawki the air temperature difference between the built up area and the open space shows a small dependence on temperature changes in the surroundings (—0.4°C/°C), whereas in the larger housing quarter of Służew nad Dolinką, similarly as in the morning hours, temperature growth is accompanied by a growth of negative temperature diffe-

rences (—0.18°C/°C). In the evening, with a drop of air temperature, differences between values within the quarters and outside them grow — on the average by about 0.3°C/°C, thus the housing quarters become warmer when compared to the surroundings.

Thus there is a conclusion that the air within a housing quarter warms up by about 1/5 less intensively in the morning hours, and in the evening cools down with intensity by 1/3 lower than in the surroundings. Thus the influence of buildings on the air temperature field is the highest early in the morning and late in the evening.

Spatial differentiation of regression coefficients in the housing quarters under study during the day is determined by exposure to the sun, distance between buildings and conditions of local air circulation. That is why in some points the regression coefficients are positive and in others they are highly negative. The highest value (—1.1°C/°C) has been registered in the quarter Służew nad Dolinką, at point 2 located on the edge of the quarter in a narrow passage between buildings (Table 2).

The equations of regression lines determine relative changes in heat island with reference to the surrounding temperature. Dependence of the difference of an average temperature on observational points within the quarter and an external point on time (t) is presented by the following equations:

Stawki		
morning	$y = 0.342 - 0.248\ t$	$r_{ty} = -0.80$
noon	$y = -1.015 + 0.056\ t$	$r_{ty} = 0.35$
evening	$y = -0.759 + 0.280\ t$	$r_{ty} = 0.93$
Służew nad Dolinką		
morning	$y = -0.289 - 0.186\ t$	$r_{ty} = -0.77$
noon	$y = -0.652 - 0.034\ t$	$r_{ty} = -0.20$
evening	$y = -1.047 + 0.394\ t$	$r_{ty} = 0.98$

Thus a trend of changes of air temperature difference between the housing quarter and its surroundings is in both quarters negative in the morning and positive in the evening. In the morning the quarters keep getting cooler and cooler in relation to the surroundings by about 0.2°C/h, in the evening warmer and warmer by about 0.3—0.4°C/h, whereas around noon the discussed differences do not show regular changes in time.

Spatial differentiation of regression coefficients (Tables 3 and 4) shows dependence on location of measuring points. The highest negative values (—0.6°C/h) were registered in the morning in both quarters (Stawki — point 5, Służew nad Dolinką — point 14) in points located on the northern side of buildings, and the highest positive value (0.6°C/h)

Table 3

Equations of regression lines of temperature differences between the housing quarter and its surroundings (y) with respect to time (t) — Służew nad Dolinką, June—July 1982; 1,5 m above ground level

Point	Morning (7–11 a.m.)		Noon (12–4 m.p.)		Evening (5–9 p.m.)	
1	$y = 0.717 - 0.153$ t	$r_{ty} = -0.50$	$y = -0.333 - 0.200$ t	$r_{ty} = -0.80$	$y = -1.197 + 0.390$ t	$r_{ty} = 0.97$
2	$y = 0.644 - 0.147$ t	$r_{ty} = -0.41$	$y = -0.156 - 0.187$ t	$r_{ty} = -0.85$	$y = -1.147 + 0.370$ t	$r_{ty} = 0.93$
3	$y = 1.228 - 0.180$ t	$r_{ty} = -0.53$	$y = -0.817 - 0.100$ t	$r_{ty} = -0.38$	$y = -1.022 + 0.307$ t	$r_{ty} = 0.89$
4	$y = 0.792 - 0.330$ t	$r_{ty} = -0.65$	$y = -1.878 + 0.093$ t	$r_{ty} = 0.32$	$y = -0.689 + 0.333$ t	$r_{ty} = 0.91$
5	$y = 0.561 - 0.607$ t	$r_{ty} = -0.94$	$y = -1.814 + 0.900$ t	$r_{ty} = 0.21$	$y = -0.764 + 0.297$ t	$r_{ty} = 0.93$
6	$y = -0.228 + 0.007$ t	$r_{ty} = 0.03$	$y = -0.278 + 0.013$ t	$r_{ty} = 0.08$	$y = 0.794 - 0.180$ t	$r_{ty} = -0.81$
7	$y = 0.075 - 0.297$ t	$r_{ty} = -0.88$	$y = -1.433 + 0.160$ t	$r_{ty} = 0.56$	$y = -0.794 + 0.313$ t	$r_{ty} = 0.90$
8	$y = 0.056 - 0.400$ t	$r_{ty} = -0.86$	$y = -1.050 + 0.127$ t	$r_{ty} = 0.68$	$y = -0.758 + 0.250$ t	$r_{ty} = 0.87$
9	$y = 0.011 - 0.347$ t	$r_{ty} = -0.88$	$y = -1.267 + 0.200$ t	$r_{ty} = 0.69$	–	–
10	$y = -0.047 - 0.083$ t	$r_{ty} = -0.29$	$y = -0.872 + 0.300$ t	$r_{ty} = 0.86$	$y = 0.181 + 0.190$ t	$r_{ty} = 0.79$
11	$y = 0.078 - 0.120$ t	$r_{ty} = -0.40$	$y = -0.828 - 0.033$ t	$r_{ty} = -0.39$	$y = -1.086 + 0.363$ t	$r_{ty} = 0.96$
12	$y = -0.106 - 0.073$ t	$r_{ty} = -0.29$	$y = -0.925 + 0.117$ t	$r_{ty} = 0.49$	$y = -0.497 + 0.137$ t	$r_{ty} = 0.43$
13	$y = -0.206 + 0.007$ t	$r_{ty} = 0.03$	$y = -0.544 - 0.027$ t	$r_{ty} = -0.12$	$y = -1.431 + 0.470$ t	$r_{ty} = 0.94$
14	$y = 0.647 - 0.503$ t	$r_{ty} = -0.92$	$y = -1.278 + 0.187$ t	$r_{ty} = 0.80$	$y = -0.422 + 0.200$ t	$r_{ty} = 0.81$

Table 4

Equations of Regression Lines of Temperature Differences between the housing quarter and its surroundings (y) with respect to time (t) — Służew nad Dolinką, June—July 1982; 1,5 m above Ground Level

Point	Morning (7–11 a.m.)		Noon (12–4 p.m.)		Evening (5–9 p.m.)	
1	$y = 0.008 + 0.037\ t$	$r_{ty} = 0.16$	$y = 0.003 - 0.010\ t$	$r_{ty} = -.007$	$y = -1.181 + 0.357\ t$	$r_{ty} = 0.91$
2	$y = -0.969 + 0.117\ t$	$r_{ty} = 0.38$	$y = 0.692 - 0.410\ t$	$r_{ty} = -0.70$	$y = -1.225 + 0.437\ t$	$r_{ty} = 0.99$
3	$y = 0.228 - 0.047\ t$	$r_{ty} = -0.19$	$y = -0.244 + 0.067\ t$	$r_{ty} = 0.30$	$y = -1.183 + 0.460\ t$	$r_{ty} = 0.96$
4	$y = -0.278 - 0.373\ t$	$r_{ty} = -0.88$	$y = -1.692 + 0.023\ t$	$r_{ty} = 0.13$	$y = -1.603 + 0.623\ t$	$r_{ty} = 0.98$
5	$y = -0.256 - 0.107\ t$	$r_{ty} = -0.58$	$y = -0.275 - 0.103\ t$	$r_{ty} = -0.40$	$y = -0.711 + 0.280\ t$	$r_{ty} = 0.99$
6	$y = -0.886 - 0.117\ t$	$r_{ty} = -0.76$	$y = -1.075 + 0.097\ t$	$r_{ty} = 0.51$	$y = -0.864 + 0.310\ t$	$r_{ty} = 0.94$
7	$y = -0.819 - 0.290\ t$	$r_{ty} = -0.87$	$y = -1.292 + 0.170\ t$	$r_{ty} = 0.60$	$y = -0.814 + 0.250\ t$	$r_{ty} = 0.97$
8	$y = -0.228 - 0.047\ t$	$r_{ty} = -0.35$	$y = 0.217 + 0.060\ t$	$r_{ty} = 0.19$	$y = -0.436 + 0.210\ t$	$r_{ty} = 0.94$
9	$y = 0.414 - 0.130\ t$	$r_{ty} = -0.38$	$y = -0.106 - 0.327\ t$	$r_{ty} = -0.84$	$y = -1.539 + 0.513\ t$	$r_{ty} = 0.99$
10	$y = -0.094 - 0.433\ t$	$r_{ty} = -0.89$	$y = -1.783 + 0.167\ t$	$r_{ty} = 0.72$	$y = -1.006 + 0.393\ t$	$r_{ty} = 0.96$
11	$y = -0.764 - 0.290\ t$	$r_{ty} = -0.82$	$y = -0.561 + 0.020\ t$	$r_{ty} = 0.07$	$y = -0.658 + 0.337\ t$	$r_{ty} = 0.90$
12	$y = -0.181 - 0.137\ t$	$r_{ty} = -0.59$	$y = -0.506 - 0.153\ t$	$r_{ty} = -0.58$	$y = -1.349 + 0.448\ t$	$r_{ty} = 0.95$
13	$y = -0.450 + 0.020\ t$	$r_{ty} = 0.09$	$y = -0.397 - 0.023\ t$	$r_{ty} = -0.15$	$y = -1.058 + 0.437\ t$	$r_{ty} = 0.94$
14	$y = 0.528 - 0.593\ t$	$r_{ty} = -0.94$	$y = -1.458 - 0.030\ t$	$r_{ty} = -0.23$	$y = -1.164 + 0.430\ t$	$r_{ty} = 0.98$

in the evening in the housing quarter Służew (point 4), in the point located on the eastern side of a building.

If we cross the lines of regression with line $y = 0$ (Fig. 3 and 4), we receive border values of temperature as well as times of occurrence and disappearance of the heat island in the quarter. Within the smaller, more dense quarter Stawki it appears in the evening later and with lower values of air temperature than in the peripheral, scarcely

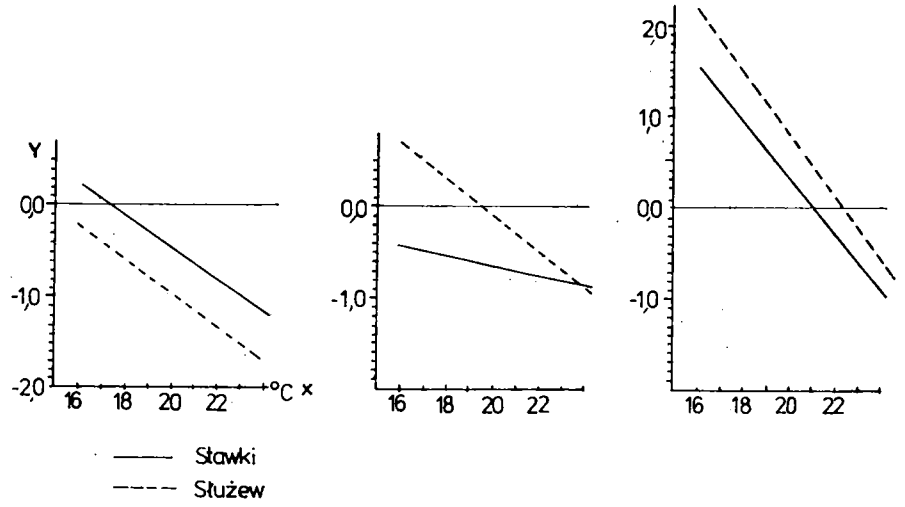

Fig. 3. Regression lines of temperature differences between the housing quarter and its surroundings with respect to the air temperature outside the quarter Służew nad Dolinką and the quarter Stawki

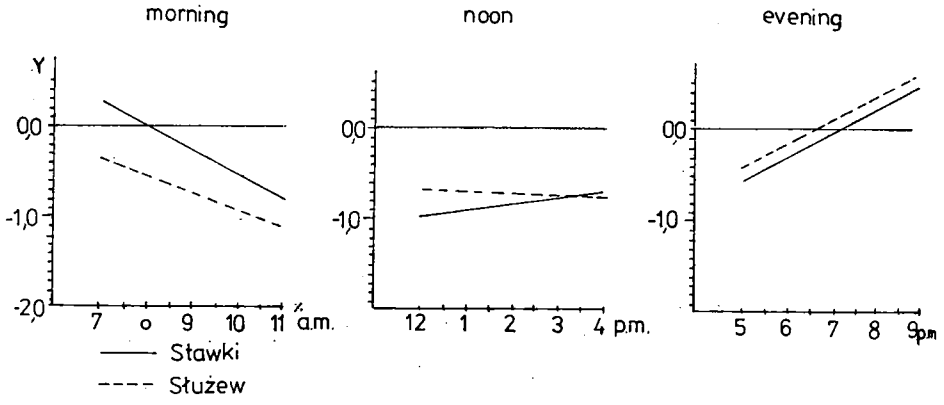

Fig. 4. Dependencies of difference of the mean air temperature on points within the quarters and an external point on time. The beginning of the time axis t = 1 are hours: morning — 7.00 a.m., noon — 12.00, evening — 5.00 p.m.

built housing quarter Służew nad Dolinką. And in the morning in the quarter Stawki the heat island keeps longer and disappears with higher temperatures.

If it is possible to determine some characteristic dependencies for various types of development, then it will be possible to make prognoses. It will be possible then to define how a town (housing quarter) should be designed to secure its inhabitants favourable bioclimatological conditions, i.e. suitable conditions of thermal feeling and suitable quantity of atmospheric air.

Knowing which urban conditions have to be fulfilled to provide man with perception of atmospheric conditions close to comfortable (on the basis of standards worked out by bioclimatology — indices of sensible climate), climate can be to some extent modified on a small scale, namely the required changes in the environment can be obtained. Under urban conditions it is possible through the formation of suitably thermically and dynamically differentiated surfaces. Thus it will be necessary to force a certain, more favourable air exchange (vertical and horizontal), secure outflow of pollution or secure suitable conditions of thermal sensation. It should be supposed that a comparative analysis of intensity of horizontal and vertical air exchange in various urban situations, coupled with an evaluation of conditions of sensible climate (by means of bioclimatological indices) will make it possible to determine optimum arrangements of housing quarters.

REFERENCES

Kaczorowska Z., 1967. „Opady Wielkiej Warszawy i jej okolic w okresie 1956—1960" [Precipitation in greater Warsaw and its surrounding in the period 1956—1960], *Przegląd Geofizyczny*, vol. 12, No. 3—4.

Kopacz-Lembowicz M., Kossowska-Cezak U., Martyn D., Olszewski K. 1984., „Wpływ zieleni miejskiej na klimat lokalny" [Impact of urban greenery on local climate], in: *Wpływ zieleni na kształtowanie środowiska miejskiego*. B. Szczepanowska (ed.), Warszawa.

Kossowska U., 1973. „Osobliwości klimatu wielkomiejskiego na przykładzie Warszawy". [Peculiarities of urban climate on the example of Warsaw], *Prace i Studia IG UW*, vol. 12

Kossowska U., 1975. Zmiany roczne różnic temperatury powietrza między śródmieściem i peryferiami Warszawy. [Annual changes of air temperature differences between the centre and suburbs of Warsaw]. *Prace i Studia IG UW*, vol. 17

Kossowska-Cezak U., 1977. „Warunki termiczne Warszawy". [Thermal conditions of Warsaw]. *Prace i Studia IG UW*, vol. 22

Stopa-Boryczka M., Kopacz-Lembowicz M., Kossowska-Cezak

U., Ryczywolska E., Wawer J., 1984, *Badania wpływu zabudowy na klimat lokalny w Warszawie.* [Studies on influence of land development on local climate in Warsaw]. Materiały I Ogólnopolskiej Konferencji nt. „Klimat i bioklimat miast", Łódź.

Stopa-Boryczka M., Kopacz-Lembowicz M., Ryczywolska E., 1980, *Wpływ zabudowy na zróżnicowanie warunków mikroklimatycznych osiedli mieszkaniowych.* [Impact of land development on differentation of microclimatic conditions of housing quarters], typescript.

Stopa-Boryczka, M., Kopacz-Lembowicz, M. Ryczywolska, E. Boryczka, J., Górka, A., 1982, „Ocena klimatu lokalnego do projektu osiedla mieszkaniowego w Białołęce Dworskiej". [Evaluation of local climate for a project of a housing quarter in Białołęka Dworska]. *Człowiek i Środowisko,* vol. 6, No. 3—4.