MILOŠ NOSEK,

Purkyně University, Brno

DYNAMIC ASPECTS OF THE URBAN CLIMATE

Dynamické aspekty městského podnebí. — Klimatologie měst je jednou z významných disciplin v současné době se formující geografie měst. Zatím je převážně věnována pozornost městskému mezoklimatu a urbanistické bioklimatologii. Je však nutno ve větší míře rozvíjet i metody zpracování makroklimatologických charakteristik městského klimatu, na něž by mohly navazovat mezoklimatologické a bioklimatologické charakteristiky a dojít tak ke komplexnímu obrazu klimatu jednotlivých měst a k vyčerpávajícímu zevšeobecnění tohoto problému.

Vhodnou cestou k tomu je studium větrných poměrů, teploty vzduchu, vlhkosti vzduchu, oblačnosti a síly (rychlosti) větru při jednotlivých, zejména převládajících směrech větrů v souvislosti s výskytem synoptických typů. Jsou-li takové analýze podrobena meteorologická pozorování všech částí města, můžeme dojít k cenným a zcela novým výsledkům z hlediska teoretického i praktického.

V článku je podána ukázka takového rozboru a hlavní výsledky jsou podány v tabulkách.

Urban climatology is one of the important disciplines of the growing science of urban geography. Up to the present the study of urban climate has been developing mostly outside the proper framework of geography as an independent branch of climatology, that is to say, partly as the subject-matter of local climatology (mesoclimatology), partly as the subject-matter of urbanistic bioclimatology.

The study of urban climate is concerned essentially with two fundamental aspects of research, and at present less attention is being paid to the macroclimatological aspects of the problem than to its local climatological (mesoclimatological) and microclimatological aspects. Thus for instance an attempt has already been made to classify the local climate of towns into types according to the local climatological regime conditioned by the character of the built-up area, the orientation of streets and squares etc. (E. Quitt).

Climatological studies of this kind are, no doubt, valuable not only from the theoretical, geographical point of view, but also as contributing important basic information for urbanistic and building practice. They are particularly important in view of the steadily growing concentration of town population and the perspective of the concentration of country population in future due to the advancing industrialisation of agricultural production.

When evaluating the local climate or microclimate of towns, we cannot do so with full responsibility unless we take into account macroclimatological condition and synoptic aspects of the climate. These are the most essential factors, particularly as regards the purity of urban atmosphere. Macroclimatological conditions in connection with the type of synoptic situation, and among these especially the direction and force (velocity) of wind, the temperature of the air, air humidity and cloudiness are most important for the planning or reconstruction of modern towns which should be in harmony or in a sort of equilibrium with the physiographical and economico-geographical conditions of the region in which the towns are situated. In most cases up till now the macroclimate of towns has been evaluated rather formally according to the characteristics obtained by so-called classical methods. Therefore in this study I should like to demonstrate on the example of Brno one of the possible applications of dynamic climatological characteristics in the evaluation of urban climate. To obtain the dynamic characteristics of macroclimatological conditions in Brno I have used the synoptic typing of M. Konček and F. Rein which is sufficiently well described in literature (F. Rein, M. Konček, M. Nosek).

The substance of dynamic climatological characteristics lies in that the description of climatic elements is not bound by the calendar interval, which, if used, serves only as a secondary parameter; it is always related to some dynamic parameter. In our case synoptic types are employed as the principal, dynamic parameter.

If we ascertain the frequency of occurence of individual synoptic types, we can on the basis of individual means or other estimated characteristics for these types express an opinion which type contributes essentially to the formation of the certain climatic character of the given place, and also what temperature, humidity etc. are typical of the given place. Moreover, it is possible to take into consideration simultaneously the whole complex of the meteorological properties of the given synoptic type. Characteristics thus obtained have then a synoptic climatological value.

An important fact is, moreover, that we can also find out the percentage of infrequently occurring types and the manner of their climatological manifestation; this is important for our problem in the case that the values thus estimated differ considerably from the average conditions.

An estimate of the share of various synoptic types in the formation of Central European climate is illustrated in Table I compiled for the seasons of the year for the period 1950/1959.

In the annual mean a substantial contribution to the formation of our climate is shared by the following eight synoptic types listed in the order of their frequency of occurence (cf. Table I): Wc, H, SWc_1, NWc, Bc, Wa, Cc, Ec. The share of the other types is relatively small. A more significant characteristic is the occurrence of synoptic types in different seasons of the year. In this respect, even some of those types whose average annual frequency is small become more significant. Such are the types NEc, Nc, NEa, Ea, SEa and SWc_2 in spring, the types SEa and Sa in autumn, and types Wcs, Ea, SWc_2 in winter.

In general, the synoptic types can be divided into three groups: the first group contains constant types which occur during the whole year, in all months; fluctuation in their occurrence is insignificant. They are: SWc_1, Bc, NWc.

Table I

Relative frequencies of occurrence of synoptic types (in %) after the catalogue of M. Konček and Fr. Rein (2). Compiled by M. Nosek.

Synoptic Type	Spring	Summer	Autumn	Winter	Year
Wc	10,1	13,8	10,9	19,9	13,7
H	10,8	14,6	16,9	9,4	13,0
SWc_1	9,4	9,5	8,9	8,2	9,0
NWc	8,0	7,5	10,1	9,7	8,8
Bc	8,6	9,0	9,3	7,1	8,5
Wa	2,7	12,8	6,5	4,4	6,7
Cc	6,4	6,7	4,5	6,4	6,0
Ec	6,0	2,5	3,0	7,3	4,6
Ea	4,8	3,0	2,2	3,9	3,4
SWc_2	4,2	2,7	2,6	3,7	3,3
SEa	4,4	0,1	5,4	3,0	3,2
NEc	5,5	3,4	1,4	2,1	3,1
NEa	4,8	3,0	2,4	1,5	3,0
NWa	3,3	2,0	3,5	3,0	2,9
Nc	5,0	2,8	1,2	1,5	2,6
Wcs	0,8	1,3	4,1	3,9	2,5
SWa	2,4	1,5	2,8	3,1	2,5
Sa	2,1	0,2	3,9	1,8	2,0
O	0,7	3,6	0,4	0,1	1,2

The second group, characterised by a marked annual variation of occurrence, comprises the types H, Wc, Cc, O, Ec, Wa, Ea, NEa, SEa, Sa. The third group comprises types with variable frequency of occurrencein course of the year, but without clearly marked annual variation. They.are the following: NWa, SWa, Wcs, SWc_2, NEc and Nc.

It can be said that the synoptic types are essentially characterised by a certain character of circulation, by cyclonic or anticyclonic activity and by certain values of climatic elements.

Air circulation elements of climatic conditions and climatological characteristics connected with them are of the greatest importance for evaluating urban climate.

Therefore very valuable information concerning urban climate can be obtained from wind-roses, especially if these are oriented on the most important climatic elements. Table II gives such wind-roses for Brno, for the seasons of the year. As evident from this table, the north-west wind direction prevails most markedly in all seasons of the year while the second prevailing wind direction is from south-east. The frequency of the later direction increases

Table II.

Wind-roses of the seasons of the year in Brno in the period 1950/59 showing air temperature — T, relative air humidity — U, cloudiness — N, and wind force in °B — ff. Frequency of directions in $^0/_{00}$ — F.

	N	NE	E	SE	S	SW	W	NW	O
Spring									
T	4,9	7,9	11,3	10,1	18,9	11,3	9,5	8,1	5,7
U	71,1	69,5	62,1	68,6	62,0	66,9	68,1	72,1	86,8
N	3,8	6,1	5,3	5,4	8,0	6,2	6,5	5,6	5,5
ff	1,8	1,9	2,4	2,1	2,5	2,0	2,0	2,0	0,0
F	7	62	2	269	1	28	34	575	22
Summer									
T	19,6	18,6	21,7	20,8	22,7	20,6	18,3	18,3	18,6
U	62,4	79,0	64,6	70,1	76,0	68,0	74,2	75,3	80,1
N	3,3	4,0	3,9	4,6	7,1	5,9	6,1	5,9	4,2
ff	2,0	1,8	1,9	1,9	1,8	2,1	2,4	2,0	0,0
F	5	36	5	229	4	44	57	589	31
Autumn									
T	6,2	8,3	13,2	9,4	17,0	9,7	10,6	8,3	6,3
U	89,6	84,8	72,3	80,1	54,0	84,1	71,5	71,8	90,1
N	5,6	6,1	2,3	5,9	0,0	5,7	6,6	6,0	4,7
ff	2,0	1,8	2,3	2,1	1,0	1,8	2,1	1,9	0,0
F	7	49	4	344	1	37	40	496	22
Winter									
T	—2,9	—1,7	—2,8	—0,2	.	2,4	0,8	—1,2	—4,6
U	71,2	81.5	82,0	85,1	.	88,9	80,1	83,3	88,8
N	7,2	6,4	4,8	7,8	.	8,3	8,9	7,4	6,7
ff	2,6	1,8	2,2	2,1	.	1,6	2,2	1,9	0,0
F	4	55	1	342	.	24	26	524	14
Year									
ff	2,1	1,8	2,2	2,1	1,3	1,9	2,2	1,9	0,0
F	6	51	3	296	2	33	40	546	23

a little in autumn and winter, while the frequency of the north-west wind direction slightly decreases in the same seasons of the year. The other wind directions are strongly suppressed which clearly reflects the influence of the terrain configuration of the Pisárky valley on the slope of which the meteorological station analysed in our study is situated.

The prolongation and opennes of this valley to the south is one of the main causes of the wind-rose deformation of low-lying ground winds.

When we follow the results given in Table II we find, for instance, that highest air temperatures are registered if the wind direction is south, but climatologically this fact is of little significance, since the frequency of occurrence of this wind direction is very small. On the other hand, of climatological importance are the values obtained during the occurrence of the two beforementioned prevailling wind directions; we may conclude that in all seasons of the year the temperatures are higher when the winds are from south-east, than they are when the winds are north-west. Relative air humidity and cloudiness are greater in spring and summer if winds are north-west than if they are south-east, in autumn and winter, on the contrary, they are greater in the case of south-east winds than they are in the case of north-west winds.

The problem is different when we try to find the respective shares of various synoptic types in this or that wind direction. Table III illustrates these shares in $^0/_{00}$ for the seasons of the year. This table makes it clear that, in essence, all synoptic types may have a share in the two prevailling wind directions; it all depends on the concrete individual situations, i.e. in which part of the cyclone or anticyclone system the given place is situated, and how the actual air flow may be deformed by the relief of the considered place.

From this point of view the climatic characteristics of wind-roses given in Table II which look very simple must in fact produce very complicated effects.

The order of sequence and importance in which individual types take share in the two prevailing wind directions and the character of their climatological effect are shown in Table IV. This table makes it also clear how the climatic characteristics of individual synoptic types vary under different wind directions. Thus, for instance, in spring with the synoptic type of anticyclone over Central Europe (H) if the wind comes from north-west the temperature is only by +0,1° C higher than is the mean of the season of the year, if the winds are from south-east it is higher by +0,8° C, in summer there is no difference between them, in the case of north-west wind direction it is lower by —0,2° C, of south-east wind direction by —0,3° C colder than is the mean of this seson. In autumn this type is considerably colder when the wind is north-west direction than when it is south-east, in winter with north-west wind it is warmer by +0,3° C, with south-east wind colder by —2,1° C than is the mean in winter.

Table III.

Frequency of wind directions in ‰ according to synoptic types and seasons of the year in Brno. Period 1950/59.

Synoptic type	N	NE	E	SE	S	SW	W	NW	Calm	Total
Spring										
Nc	.	1	.	4	.	.	3	42	1	51
NEc	.	4	.	5	.	.	.	45	.	54
Ec	1	5	1	15	.	1	2	32	1	58
SWc										
SWc_1	.	4	.	51	.	4	2	31	2	94
SWc_2	.	4	.	20	.	1	2	12	2	41
Wcs	.	1	.	.	.	2	.	4	2	9
Wc	.	6	.	17	.	4	7	63	3	100
NWc	.	2	.	2	.	2	7	66	1	80
Bc	1	5	.	29	.	4	7	36	1	83
Cc	1	2	.	19	.	2	1	40	.	65
O	1	1	.	1	.	.	.	3	1	7
H	1	4	.	27	.	3	1	70	3	109
NEa	1	8	1	3	.	.	1	34	1	49
Ea	.	11	.	14	.	1	.	21	1	48
SEa	.	2	.	32	.	1	.	8	1	44
Sa	.	.	.	17	.	.	.	4	.	21
Swa	1	1	.	7	.	1	1	13	1	25
Wa	.	1	.	4	.	2	.	21	.	28
NWa	.	.	.	2	.	.	1	30	1	34
Summer										
Nc	1	1	.	1	.	.	1	22	1	27
NEc	.	1	.	5	.	1	3	22	1	33
Ec	1	2	.	5	.	1	1	16	.	26
SWc_1	.	2	.	43	1	4	6	36	5	97
SWc_2	.	.	.	9	.	1	1	13	1	25
Wcs	.	1	.	1	.	1	1	8	1	13
Wc	.	3	1	29	1	10	9	84	2	139
NWc	1	1	.	3	.	2	6	61	1	75
Bc	.	3	.	22	.	4	4	56	2	91
Cc	.	4	1	20	2	3	5	31	3	69
O	.	1	.	10	.	4	.	20	1	36
H	.	4	1	38	.	7	5	88	3	146
NEa	.	.	.	4	.	1	.	18	2	25
Ea	.	6	1	11	.	.	.	12	.	30
SEa	.	.	.	1	.	.	.	1	.	2
Sa	1	.	1	1	.	.	.	.	1	4
SWa	.	.	.	6	.	1	1	7	1	16
Wa	1	6	.	20	.	3	13	79	5	127
NWa	.	1	.	.	.	1	1	15	1	19

Synoptic type	N	NE	E	SE	S	SW	W	NW	Calm	Total
Autumn										
Nc	.	1	.	.	.	.	.	10	.	11
NEc	1	2	.	4	.	.	.	8	.	15
Ec	.	2	.	4	.	2	1	21	.	30
SWc_1	.	3	.	58	.	2	1	25	2	91
SWc_2	.	1	1	11	.	2	1	11	1	28
Wcs	.	2	.	11	.	1	4	24	.	42
Wc	.	6	2	28	.	9	11	50	4	110
NWc	1	3	.	7	.	4	8	78	1	102
Bc	1	5	.	35	.	2	3	44	2	92
Cc	2	2	.	13	.	3	.	24	1	45
O	.	.	.	.	.	.	.	4	.	4
H	1	4	1	69	.	5	4	78	6	168
NEa	.	1	.	2	.	.	.	13	1	17
Ea	.	6	.	4	.	2	.	10	.	22
SEa	.	2	.	32	.	.	.	19	1	54
Sa	.	1	.	33	.	.	.	4	1	39
SWa	.	2	.	17	.	.	.	8	1	28
Wa	1	4	.	14	.	4	5	37	1	66
NWa	.	2	.	2	.	2	2	28	.	36
Winter										
Nc	.	1	.	1	.	.	.	14	.	16
NEc	.	2	.	1	.	.	.	18	.	21
Ec	1	7	.	20	.	1	1	43	2	75
SWc_1	.	1	.	56	.	2	2	19	1	81
SWc_2	.	.	.	27	.	1	.	10	.	38
Wcs	.	3	.	11	.	3	.	20	2	39
Wc	.	13	.	71	.	9	11	93	1	198
NWc	.	4	.	10	.	.	7	74	2	97
Bc	.	4	.	19	.	2	.	44	2	71
Cc	1	1	.	22	.	1	2	36	2	65
O	.	.	.	1	.	.	.	.	.	1
H	.	5	.	29	.	2	1	57	1	95
NEa	2	2	.	.	.	.	.	12	.	16
Ea	.	5	1	9	.	1	1	19	.	36
SEa	.	2	.	24	.	.	.	3	.	29
Sa	.	.	.	13	.	.	.	3	1	17
SWa	.	2	.	23	.	.	.	6	.	31
Wa	.	3	11	11	.	2	1	28	.	45
NWa	.	.	.	3	.	.	1	25	.	29

Deviations of air temperature (dT), relative humidity (dU), cloudiness (dN) and wind-force (dff) directions — NW (F) and SE (F) in the seasons of the year in Brno for the period 1950/59. The occurrence of all wind directions. Synoptic types with frequency of less than 20 $^0/_{00}$ are given

SPRING

Wind direction											
NW						SE					
F	ST	dT	dU	dN	dff	F	ST	dT	dU	dN	dff
70	H	+0,1	— 6,5	+0,8	+0,1	51	SWc_1	+1,7	+ 3,3	+1,3	+0,2
66	NWc	—8,8	+ 0,7	+1,3	+0,3	32	SEa	+0,4	— 2,7	—1,2	+0,8
63	Wc	+1,7	— 0,6	+1,1	+0,4	29	Bc	+3,7	+ 3,7	+1,3	+0,2
45	NEc	—2,3	+ 3,5	+1,6	+0,2	27	H	+0,8	— 5,2	—3,1	—0,3
42	Nc	—2,8	— 1,8	+0,6	+0,5	20	SWc_2	+3,7	+ 1,5	—0,7	—0,1
40	Cc	+0,5	+22,9	+4,4	0,0	19	Cc	+0,6	+10,3	+3,1	+0,1
36	Bc	+2,9	—14,3	+1,3	+0,4	17	Wc	+0,1	+ 4,6	—0,1	+0,1
34	NEa	—5,3	— 6,2	—0,4	+0,2	17	Sa	—1,2	+ 2,9	—2,8	+0,1
32	Ec	—0,7	+ 1,0	+1,3	+0,2						
31	SWc_1	+1,3	+10,3	+2,0	—0,3						
30	NWa	—1,1	— 9,0	—1,9	+0,2						
21	Ea	+1,6	— 5,8	—1,6	0,0						
21	Wa	+0,8	— 9,5	—0,5	—0,1						

SUMMER

Wind direction											
NW						SE					
F	ST	dT	dU	dN	dff	F	ST	dT	dU	dN	dff
88	H	—0,3	+ 5,5	—2,7	—0,1	43	SWc_1	+1,3	— 1,4	—0,2	+0,2
84	Wc	—0,3	— 0,7	—0,1	0,0	38	H	—0,2	— 4,7	—2,7	—0,2
79	Wa	+0,6	— 3,2	—1,2	—0,1	29	Wc	—1,0	+ 3,7	+1,5	—0,1
61	NWc	—1,9	— 0,9	—0,1	+0,2	22	Bc	+0,1	+ 0,3	+0,4	+0,2
56	Bc	—0,6	+ 5,0	+1,3	+0,1	20	Cc	—1,7	+ 6,5	+1,6	0,0
36	SWc_1	+1,0	— 3,3	—0,3	0,0	20	Wa	+1,0	+ 1,8	—0,9	+0,1
31	Cc	—2,3	+11,0	+2,8	+0,1						
22	Nc	—1,7	— 2,0	+0,9	+0,2						
22	NEc	+0,5	+ 0,1	—0,1	+0,1						
20	O	+1,4	— 2,3	—1,3	—0,2						

from the means corresponding to the given direction of the wind for the two prevailing wind share of individual synoptic types (ST) in the given wind direction is expressed in $^0/_{00}$: of the total exceptionally only. The table is compiled according to the following scheme: F ST dT dU dN dff.

AUTUMN

Wind direction											
NW						SE					
F	ST	dT	dU	dN	dff	F	ST	dT	dU	dN	dff
78	H	+0,6	+ 8,5	—1,6	0,0	69	H	—0,2	—0,7	—1,8	—0,3
78	NWc	—0,1	+ 6,8	+1,3	+0,3	58	SEc_1	+2,3	+1,1	+1,3	+0,1
50	Wc	+0,9	+ 8,6	+1,2	+0,3	35	Bc	+1,8	+7,1	+2,9	—0,2
44	Bc	+1,5	+15,3	+2,7	+0,2	33	Sa	+1,5	—1,3	0,0	+0,6
36	Wa	+0,8	+22,2	—0,5	—0,2	31	SEa	—0,2	—4,3	—1,3	+0,3
28	NWa	+0,1	+ 6,2	+0,4	+0,2	28	Wc	0,0	+7,9	+1,9	—0,4
25	Ec	—0,3	+11,0	+0,4	+0,1	17	SWa	—0,3	+0,3	—1,6	0,0
24	Wcs	—0,8	+16,1	+1,9	+0,2						
24	Cc	+0,2	+13,8	+2,4	+0,1						
21	Ec	+0,3	+11,0	+0,4	+0,1						
20	SEa	+0,3	+ 6,8	—2,0	—0,1						

WINTER

Wind direction											
NW						SE					
F	ST	dT	dU	dN	dff	F	ST	dT	dU	dN	dff
93	Wc	+3,1	— 1,3	0,0	+0,1	71	Wc	+13,	+3,6	+1,0	—0,2
74	NWc	+2,6	— 3,0	+0,4	+0,6	56	SWc_1	+4,0	+2,3	+1,4	+0,2
57	H	+0,3	— 0,6	—1,8	0,0	29	H	—2,1	+0,1	—1,0	—0,3
44	Bc	+0,2	0,0	+0,7	—0,1	27	SWc_2	+0,8	+7,5	+1,4	—0,1
43	Ec	—1,9	— 2,9	+0,8	+0,1	24	SEa	—5,2	—7,0	—1,7	+0,3
36	Cc	+3,7	+ 6,5	+1,6	—0,1	23	SWa	—2,2	+5,1	+0,2	+0,2
28	Wa	+2,4	+ 0,8	—1,4	—0,1	22	Cc	+1,6	+4,3	+1,3	0,0
35	NWa	—1,8	— 6,6	—1,4	+0,6	20	Ec	—1,2	+2,1	+1,4	+0,1
20	Wcs	+2,2	— 3,4	—1,2	+0,6	19	Bc	+2,4	+2,4	+1,8	+0,4
19	Ea	—4,0	— 5,1	+0,7	—0,1						
19	SWc_1	+2,3	+ 3,2	+1,7	+0,3						
18	NEc	—1,6	—11,8	+1,2	+0,6						

It is evident that these characteristics acquire their full meaning only if we analyse in this way the data of meteorological stations in those parts of the town which are distinct topographically, expositionally and urbanistically. In this way only can we in a fully exhaustive and synthetic manner define the meaning of the weatherside and the leeward side of the town and form an idea of its wind system and its connections with the total urban climatological regime.

Literature

KONČEK M.: Vzťah medzi synoptickou situáciou a počasím na južných svahoch Vysokých Tatier. Meteorologie Karpát. Bratislava 1961.

KONČEK M.—REIN FR.: Kalendář synoptických typů za období 1950/1959. Manuscript.

NOSEK M.: Dynamická klimatologie jako prostředek geografického výzkumu. Sborník čsl. spol. zeměpisné, Praha 1963.

REIN F.: Weather Typing with Regard to Dynamic Climatology. Studia geophysica et geodetica. Praha 1959.

QUITT E.: Methods of the Establishment of Mesoclimatological Areas in Towns. Sborník čsl. spol. zeměpisné, Praha 1964.