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CHANGES OF CONVECTIVE WEATHER FOUND IN KATOWICE (1966-1996)

Abstract: In this paper the convective weather was defined on the basis of the relationship between the temperature gradient, that was measured in Sosnowiec, in about 100 m air layer, the value of temperature increase within 3 hours and type of clouds. The changes of convective weather were investigated throughout the year and during the day, and they were interpreted as a result of circulation variability and the human influences. The increasing trend of the anticyclonic situations (favourable of convection), and development of Katowice (representing the biggest agglomeration in Poland), cause the rise of considered weather type.

Key words: convective weather, gradient measurements, urban climate.

1. Introduction

In the second half of the 20th century the human activity influences more and more the climate – especially in local scale. The climate conditions are mainly modificated in large urban areas, where such characteristic phenomena as urban heat island or urban breeze, caused by intensive local convection, occur. These phenomena are more and more visible together with the development of urbanisation, but their frequency depends first of all on meteorological conditions. The most favourable are anticyclonic circulation types (Lewińska 1990; Oke 1996; Barry, Chorley 1998).

The aim of this work is an analysis of convective weather frequency in Katowice – the city representing Upper Silesia Region, the biggest agglomeration in Poland. In the period 1966-1996 Katowice went under significant development, which might be indicated by the growth of population from 288 thousand in 1966 to 351 thousand in 1996. Changes of convective weather will be explained by the increase of anthropopression and by variability of circulation.

2. Data and Methods

The basic data originate from Katowice-Muchowiec synoptic station and cover the period 1966-1996. Data related to circulation come from atmospheric circulation calendar prepared by Niedźwiedź for upper Vistula region. Moreover the data from Sosnowiec, for the years 1993-1996 were taken to define the convective weather.

The meteorological station in Sosnowiec is situated several kilometres from Katowice. The automatic measurements of air temperature are taken there at two levels above the ground: 2 m, in the meteorological garden and 95 m, on the roof of the building of Faculty of Earth Sciences, Silesian University. The building is located 50 m from meteorological garden.

To find meteorological conditions favourable of convection, conditional probability of unstable atmosphere occurrence was counted, in different weather situations. The convection may be caused by two reasons: „by buoyant, results from differences in temperature and density within the atmosphere" (Schneider 1996), during a heating of air layer near surface, or „by mechanical forces as air masses are forced to rise over some obstacle" (Schneider 1996; Gryboś, Tomaszek 1997; Scorer 1997). In this study only the second process will be considered. Values of temperature change within 3 hours were investigated as the generative factor of convection, while the low level clouds were considered the effect of convection and investigated as such.

The conditional probability of unstable atmosphere occurrence (temperature gradient $\gamma \geq 0.5$K) exceeds 50% when temperature increase at 2 m above ground is greater then 2 K within 3 hours (Tab. 1). The cloudiness data were taken from Katowice, because the visual observations are not made in Sosnowiec. Unstable atmosphere occurs with the greatest conditional probability (above 50%) when such clouds like Cu hum, Cu med, Cb and Cu with Sc are observed (Tab. 2).

Tab. 1. Conditional probability of unstable atmosphere ($\gamma \geq 0.5$ K) in Sosnowiec, depending on temperature changes (ΔT) during 3 hours.

ΔT K during 3 hours	Cooling					Heating				
	≤ 8	7.9 - 6	5.9 – 4	3.9 - 2	1.9 - 0	0.1 - 2	2.1 - 4	4.1 - 6	6.1 - 8	>8
P % $\gamma \geq 0.5$ K	16	15	7	9	22	41	56	56	58	62

Tab. 2. Conditional probability of unstable atmosphere ($\gamma \geq 5$ K) in Sosnowiec, depending on the type of low level clouds.

Cloud types	Cloud-less	Cu hum	Cu med	Cb calv	Sc cugen	Sc	St	St + Cu	Cu + Sc	Cb capi
P % $\gamma \geq 5$ K	19	67	62	69	26	28	28	42	62	50

The most favourable conditions for the development of convection occur when the air at 2 m above the ground heats quicker than 2 K during 3 hours, and the clouds Cu, Cb, and Cu with Sc appear as an effect of this process. Conditional probability of unstable atmosphere amounts to 75% in such circumstances. However, it should be pointed that convection defined by this method equals 20% of all cases of unstable atmosphere in Sosnowiec.

3. Long-Term Changes of Convective Weather throughout the Year and during the Day

In this paper the frequency of convective conditions is presented as a percentage of all considered measurements. The contribution of convection in all observed weather types fluctuated in the years 1966-1996 from 5.1% in 1967 to 7.2% in 1990 and 1991 (Fig. 1). The most significant year-to-year changes occurred in 1975/1976 and 1995/1996. In both cases there was a decrease of convective weather frequency,

Fig. 1. Changes of convective weather frequency in Katowice in the years 1996-1996.

which amounted to 1.2% and 1.4% respectively. The greatest increase equals 1.0% and was noted in 1993/1994. So in the 90's there were observed relatively large fluctuations of convection frequency. However, generally convection is getting more and more frequent, about 0.4% per 10 years on average. The equation of linear trend is statistically significant at the 99% confidence level.

Convective weather occurs in Katowice first of all in warm season, with maximum in June: 12.5% (Fig. 2), but sporadically it also appears in cold months. This fact may be connected with urban heat island, which causes faster disappearing of snow cover (Falarz 1998). In addition snow is removed by municipal services from roads and streets. For these reasons albedo is smaller and it favours heating the air layer near the ground and the development of convection.

Fig. 2. Frequency of convective weather in particular months in Katowice.

Long-term changes of convection frequency, similarly to the yearly course, show increasing tendency in all months (Tab. 3). The biggest growth, statistically significant at the 99% confidence level, follows in July and amounts to 1.2% per 10 years. It should be also noticed that there is quite a distinct increase of frequency of convective weather in February and March, both statistically significant at the 95% confidence level.

Tab. 3. Trends of convection weather frequency in particular months in Katowice.

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a	0.008	0.036	0.066	0.019	0.051	0.079	0.116	0.027	0.002	0.007	0.015	0.012
R^2	0.03	0.15	0.13	0.01	0.06	0.08	0.37	0.02	0.00	0.00	0.03	0.09
Significance	-	95%	95%	-	-	-	99%	-	-	-	-	-

The diurnal course of convective weather in Katowice shows maximum at 9 GMT, amounting to 226% (Fig. 3). After 15 GMT convection disappears and starts to develop again as soon as the Sun rises. Such quite an early development of convection processes is another fact providing the urban influence on the considered phenomenon. Urban heat island makes nocturnal temperature inversions weaker and

Fig. 3. Frequency of convective weather in particular hours in Katowice.

more seldom and in the consequence the air layer near the ground is heated faster. Thus the convective cell forms.

In all daytime observations there are rising tendencies of convective weather frequency (Tab. 4). The biggest rise is in the case of midday term and amounts to about 1.7% per 10 years, with statistical significance at the 99% confidence level.

Tab. 4. Trends of convection weather frequency in particular hours in Katowice.

Hours	6 GMT	9 GMT	12 GMT	15 GMT
a	0.0324	0.0622	0.1707	0.0255
R^2	0.13	0.04	0.36	0.08
Significance	-	-	99%	-

4. The Relationship between Convective Weather and Types of Atmospheric Circulation

To find circulation types favourable for the development of convection the conditional probability of convection weather was calculated, for particular synoptic situations after Niedźwiedź (1981). Hundred percent means that all days have the same type of circulation.

At 9 GMT the most favourable are anticyclonic circulation types with air advection from NE, N and NW (Tab. 5). The intensification of convection follows in

Tab. 5. Conditional probability of convection (P%) at 9 and 12 GMT, for particular circulation types after Niedźwiedź (1981), in Katowice.

Anticyclonic	Numbers of day (100%)	P % at 9 GMT	P % at 12 GMT	Cyclonic	Numbers of day (100%)	P % at 9 GMT	P % at 12 GMT
N	332	43.1	29.5	N	319	16.9	15.0
NE	369	50.9	24.4	NE	276	19.6	15.9
E	516	29.1	19.0	E	292	19.5	17.1
SE	518	10.4	16.4	SE	274	13.1	16.1
S	407	8.4	18.2	S	345	11.9	17.7
SW	425	6.6	21.9	SW	603	17.1	24.0
W	875	23.2	20.2	W	1224	21.6	18.1
NW	528	32.0	22.9	NW	684	19.4	17.5
Centre	364	22.0	23.1	Centre	150	17.3	14.7
Wedge	1405	30.5	33.2	Trough	1164	22.6	22.3
Cannot be classified					253	22.1	23.7

this case from the advection of cold air over warm ground. Convection develops with big probability also in the situation when southern Poland is under the influence of anticyclonic wedge.The development of convection processes before midday shows bigger connection with atmospheric circulation than the one at 12 GMT, when maximum temperature occurs in Katowice. The same relation is observed in the case of Cu clouds occurring in Cracow (Matuszko 1998).

The long-term variability of circulation types frequency, the most important factor for convection processes (Fig. 4), explains to great extent the long-term variability of convective weather occurrence (Fig. 1). The frequency of anticyclonic wedge shows rising tendency in the considered period, significant at the 99% confidence level. The rising tendency of the frequency of anticyclonic situations

Fig. 4. Changes of frequencies of anticyclonic situations with advection from NE, N and NW and anticyclonic wedge in the years 1966-1996.

with air advection from northern sector is also quite distinct and significant at the 95% confidence level, although generally, anticyclonic situations show decreasing trend in a hundred-year period (Niedźwiedź 1998).

5. Conclusions

The analysis of convective weather changes in Katowice showed not very big but distinct increasing tendency in the years 1966-1996. During a year the biggest growth of convective weather frequency occurs in July and during a day – at 12 GMT. The main factor influencing the changes of this phenomenon is the circulation variability, especially the rise of frequencies of anticyclonic situations with air advection from northern sector and anticyclonic wedge. These circulation types are the most favourable for development of convection. The influence of urban heat island is demonstrated by the increase of considered weather type in cold months and in morning hours.

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