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LONG-TERM OBSERVATION OF CLOUD COVER IN CRACOW (1792-1999)

Abstract: Cracow's series of nephological observations is unique in European scale. Both the place of observations and the methods of estimating the cloudiness degree and defining the cloud genera have not changed significantly for about one hundred years. The paper presents the data base about the cloudiness in Cracow together with the possibilities of its application in both local and global scale.

Key words: Cracow, cloudiness, cloud genera, nephological conditions.

1. Introduction

The Meteorological Station of the Climatology Department at the Jagiellonian University in Cracow (ϕ = 50°04 N, λ = 19°58 E, h = 206 m above sea level) is one of the most unique stations in Europe, which can boast long and, what is most important, continuous observation of cloud cover. The "atmosphere status" has been recorded since the station's foundation, i.e. from 1792. At first, the report on cloud cover concerned only its size and was irregular. Systematic reports date from 1853, when the 10-grade scale of cloud cover was introduced. First quality records of clouds date from December 1862, but describe only four types: cumulous H, stratified S, cirrous-stratified FS, and cumulous-stratified HS, which were recorded only at noon. According to the new classification, which employed Latin names introduced by Howard, clouds were observed from September 1886, although at first sporadically and only at 2 PM. In the "year of international observations", i.e. from May 1896 to May 1897, clouds were recorded three times a day, unfortunately, later to fall back down to one observation at noon. Since 1904, clouds have been discerned according to the International Cloud Atlas, three times a day. This date marks the beginning of uniform nephological observations in Cracow. Both the place itself and the method for estimation of cloud cover and definition of cloud genera have not been significantly altered for almost one hundred years.

The aim of this study is to present the database on cloud cover in Cracow and to point to its possible applications both on local and on global scale.

2. Database

The source of databank on the cloud cover in Cracow are the archive materials from daily nephological observations from the years 1792-1999, which belong to the Climatology Department at the Institute of Geography of the Jagiellonian University.

1. Daily Records of Meteorological Observations, so called Great Books, which contain the results of the observations at given times of day.

2. Lists of Monthly Meteorological Observations, so called Middle Books, which contain the values per day.

The records of nephological conditions encompasses the size of cloud cover and cloud genera noted as letters. Ten cloud genera have been accounted for, according to the International Cloud Atlas: Cirrus Ci, Cirrocumulus Cc, Cirrostratus Cs, Altocumulus Ac, Altostratus As, Stratocumulus Sc, Stratus St, Nimbostratus, Ns, Cumulus Cu, and Cumulonimbus Cb. Average values of cloud cover have been calculated for all cloud genera, using 11-degree scale (1-10). The data from the period between 1989-1999 have been transformed from 9-degree scale to 11-degree scale.

3. Possible Applications of the Long-Term Nephological Observations in Cracow

"Metadata", i.e. information on the history of nephological research in Cracow, is crucial for scientific research. Very few meteorological stations in the world have so long and continuous series of measurements with full observatory documentation. Archive materials from this station serve as a reference point for research on the changes of climate in Central Europe, as according to Obrębska-Starklowa (1993) the climatic variations in Cracow are representative for this region of Europe.

The Cracow database on cloud cover may be applied to:

1. assess the long-term variability of nephological conditions,

2. study the relation between the cloud cover and cloud genera vs circulation and anthropogenic factors,

3. define the structure of cloud cover of the town situated in a foothill valley.

1) In Cracow one may observe, similarly to other regions of the world (London et al. 1991; Nicholls et al. 1996), the increased frequency of occurrence of certain cloud genera (Ci, Ac, Sc, Cu and Cb), and a decreased frequency of other cloud genera (Cc, Cs, Ns, St and fogs).

The growing trend in the long-term course of occurrence of Cu cloud (Fig. 1) is probably related to circulation factors, as such tendencies are observed in the entire

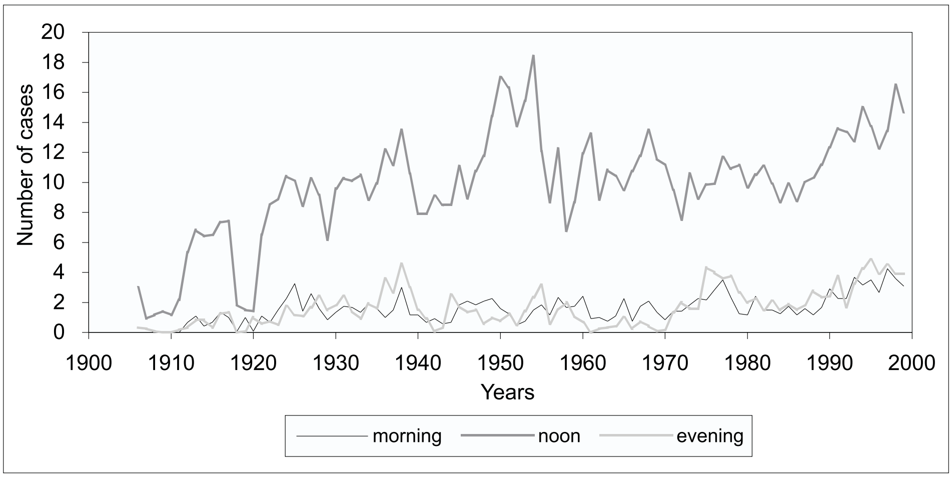

Fig. 1. Multi-annual course of the Cu cloud genus frequency in Cracow (1906-1999).

Europe, and to the impact of the surface. Intense urbanisation of Cracow causes the constant decrease in green areas and the increase in artificial concrete surfaces, which causes strong convection. Similar effects of the thermal impact of the urban architecture on cloud cover have been pointed out by Kossowska-Cezak (1978) for Warsaw. In the long-term course of occurrence of Cu clouds, noon observations are especially significant because the clouds reach their maximum occurrence frequency due to their convection origin. The highest values (exceeding 14 occurrences) for Cu clouds fall on the period between 1948 and 1955; while the lowest values (below 2 occurrences) for the first five years of the course. In the last ten years, the increase was observed in the frequency of occurrence of Cu cloud, which has been recorded for all three observation times.

The long-term course of occurrence of Ns clouds (Fig. 2) shows a decreasing tendency. Until the 1920's, the values did not exceed 10 cases per month. In 1923 maximum frequency was recorded (15 cases), and later a decisive fall, as the years 1924-1936 were characterised by lower values (about 6 cases). In the subsequent years, there was another rise in the frequency of occurrence of Ns clouds. Since the 1940's the frequency of occurrence of Ns clouds has been showing a visible decreasing tendency, and since the 1960's – almost constant low values (about 2 cases). Probably at the very beginning of the course the occurrence frequency has been exaggerated due to imprecise cloud classification used until 1932, which employed rain cloud Nimbus (Matuszko, Bielec 1998). In a later period the decrease was probably related to circulation factors; increase in the activity of the high causes the weakening of zone circulation favourable for Ns cloud formation.

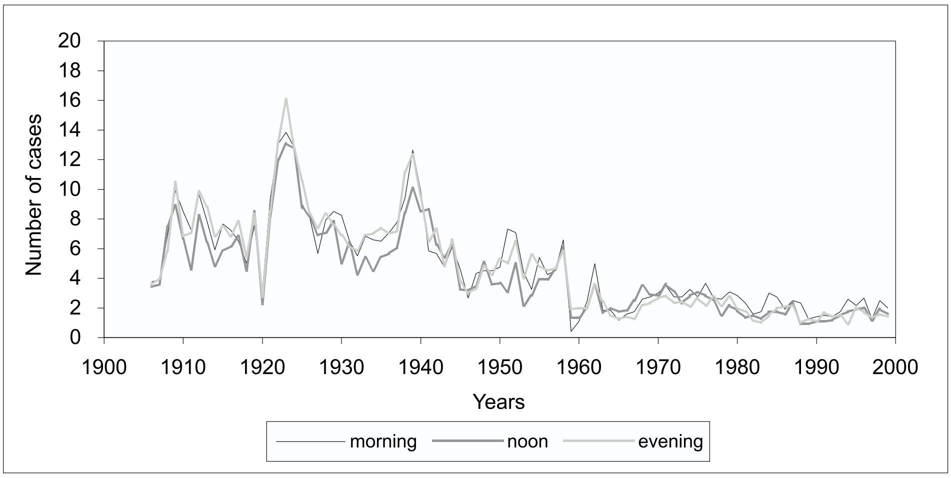

Fig. 2. Multi-annual course of the Ns cloud genus frequency in Cracow (1906-1999).

2) The cloud cover's dependence on circulation and local factors is a complex problem due to various feedback. Henderson-Sellers (1986) calls this research speculative because of difficulties in defining whether the cloud cover increase resulting from temperature rise and therefore increased evaporation, leads to the increase in cloud cover (St clouds) or to the increase in the vertical development (Cu clouds) even with a possible decrease in the horizontal range. The existence of an almost one-hundred-year-long series of nephological observations helps to find out quantitative relations between the cloud cover and air circulation, and allows for creating a forecast model for cloud genera, depending on synoptic situation. This model makes it possible to define in percentage the probability of occurrence of particular cloud genera at arbitrarily selected (forecasted) synoptic situation (for each month at noon).

The impact of anthropogenic factors on quantitative and qualitative variability of cloud cover in Cracow in the long-term period may be defined on the basis of the changes in annual cloud cover and occurrence of clouds from low étage, as well as through comparing the nephological conditions in the city and out of the urban area.

The example of Cracow proves that the city causes the increase in occurrence of Cu and Cb clouds, probably due to emission of artificial heat into the atmosphere and convection over the heated concrete surfaces. One can also observe the decrease in occurrence of low Stratus clouds due to drying of air over the city, which in consequence causes the fall in cloud cover.

3) The comparison of nephological conditions of Cracow and other towns may be an attempt to define tendencies in the structure of cloud cover on a highly urbanised area situated in a foothill valley:

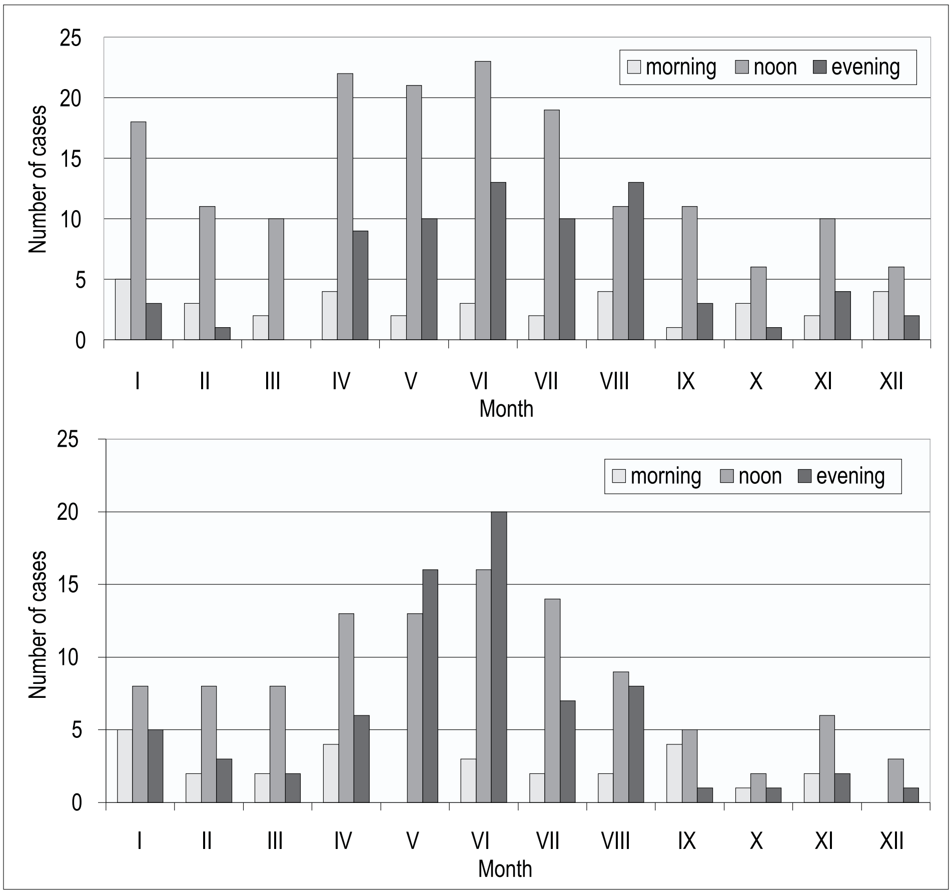

Fig. 3. Annual course of the Cb cloud frequency in: a) Cracow, b) Balice and the monthly averages of their appearance in the climatological terms (1906-1999).

· Thick cloud cover (on the example of Cracow and Prague for the period between 1906 and 1960; on average of 10% higher than in other towns), related to the location in a weakly aired, humid foothill valley with a large river. It is also caused by weak air change due to remaining inversion layers and high number of condensation nuclei, resulting from air pollution over the city.

· Predominance of St clouds among other cloud genera, which is a consequence of radiation cooling processes in a foothill valley, and high humidity over wetlands in the valley, which are favourable for formation of fog and low Stratus clouds.

· Increased occurrence of Cu and Cb clouds. The impact of the city through heating of lower layers of the atmosphere causes the development of unstable equilibrium and formation of convection-type clouds unless there is strong thermal inversion at the moment.

Tab. 1. Probability of occurrence (in %) of particular cloud genera and cloudless weather (Bch) at noon, with various synoptic situations in Cracow (July 1906-1999).

Type		Genera of clouds										
		Ci	Cc	Cs	Ac	As	Ns	Sc	St	Cu	Cb	Bch
1	Na	7	3	3	13	7	4	13	1	39	8	1
2	NEa	8	3	4	16	6	4	13	1	34	8	3
3	Ea	10	3	12	10	6	4	7	2	38	4	5
4	SEa	12	7	18	11	5	5	2	0	32	4	5
5	Sa	12	5	8	12	3	1	7	0	37	7	8
6	SWa	16	8	6	22	1	0	4	1	34	1	6
7	Wa	8	3	5	15	8	4	14	3	33	5	1
8	NWa	5	3	2	17	7	6	18	3	31	8	1
9	Ca	15	4	9	4	6	1	9	0	37	5	10
10	Ka	12	3	7	15	7	2	7	2	36	4	6
11	Nc	4	1	1	10	8	19	19	7	24	7	0
12	NEc	1	1	2	14	9	12	18	7	25	10	1
13	Ec	4	4	4	16	10	1	15	7	28	9	0
14	SEc	12	3	9	12	11	11	11	3	26	4	0
15	Sc	13	7	4	16	3	7	8	3	31	6	2
16	SWc	11	8	10	14	12	2	7	1	28	5	2
17	Wc	6	3	5	15	10	9	15	5	26	5	0
18	NWc	3	2	3	15	11	15	17	5	22	7	0
19	Cc	5	2	8	8	8	13	11	8	22	16	2
20	Bc	6	4	6	14	10	10	12	4	27	8	0
21	X	14	9	5	16	5	2	12	2	28	7	0

Tab. 2. Amount of cloudiness (in %) in Cracow, Lublin, Rzeszów, Przemyśl, Prague in the period 1947-1956.

Stations	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Cracow	82	81	73	69	68	71	65	64	63	70	85	85	73
Lublin	78	73	61	57	53	57	54	52	50	57	78	79	62
Rzeszów	74	73	68	61	60	62	57	54	52	59	77	77	65
Przemyśl	72	72	66	59	57	60	55	50	50	58	77	75	62
Prague	79	76	66	65	62	63	63	59	58	69	81	83	69

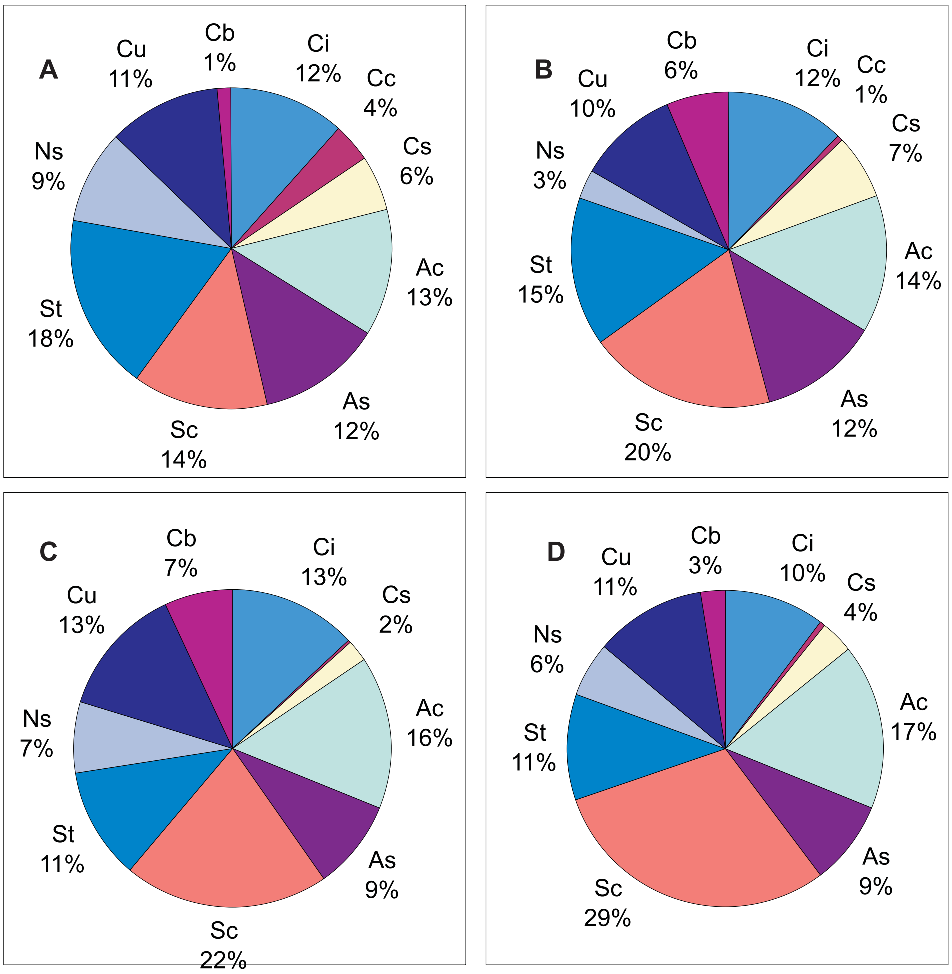

Fig. 4. Percentage of cloud genera in: a) Cracow, b) Lublin, c) Przemyśl, d) Rzeszów (1947-1956).

4. Conclusions

This study confirms the conviction that the Cracow series of cloud observations may form a basis for scientific analyses and comparisons, and may prove helpful in constructing climatic models, in which the cloud cover is still the lacking element. The application of both quantitative (degree to which the sky is covered in clouds) and the qualitative (cloud genera) approach to the problem, based on a long and uniform series of nephological observations conducted from the ground, may help to supplement the results obtained from modern, satellite research on clouds.

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