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Krzysztof Olszewski

THE ROLE OF AIR MASS TYPES IN SHAPING TWENTY-FOUR HOURS' VARIATIONS IN CLOUDINESS

For a long time, the idea that the interrelation between cloudiness and types of air mass should be investigated, has been put forward. Until now, however, attempts to solve this problem have been taken by Warakomski only (1969); the author discussed the role of the kinds of air mass in shaping the cloud types. Yet, it seems that twenty-four hours' variations in the cloudiness volume should be given a more thorough examination as they play a definite role in synoptic meteorology.

The data for the present study is based on hour by-hour observations that were conducted at the Warsaw-Okęcie station within the time span of 1956—1960. In differentiating various kinds of air mass, a geographical division was referred to, and the restriction was also made to the following main types: the maritime polar air mass (mP) and the continental one (cP) as well as the arctic air mass (A).

Within the five years' time that was covered by the present study; the mean twenty-four hours' cloudiness varied from 60% in Autumn, up to 85% in Winter (Fig. 1). Variations of those mean values within a year have a complex shape: the greatest cloudiness (above 80%) can be observed from November until January, the lowest (about 60%) — from March until September; but, at the same time, there is a considerable increase in cloudiness in April and in July.

Two types of twenty-four hours variations can be distinguished: one is characteristic of the winter time and the early Spring; the other is specific of the warm season. From January until March, the occurrence of the "winter"-type with the distinctive feature of small amplitudes can be noted. The time of the day when there is the greatest cloudiness is its another characteristic feature. It can be observed around 7—8 a.m., then during the day time it gradually lowers to reach the minimum value between 9 p.m. — 1 a.m.

The "summer"-type is specific of the April-December period. In this

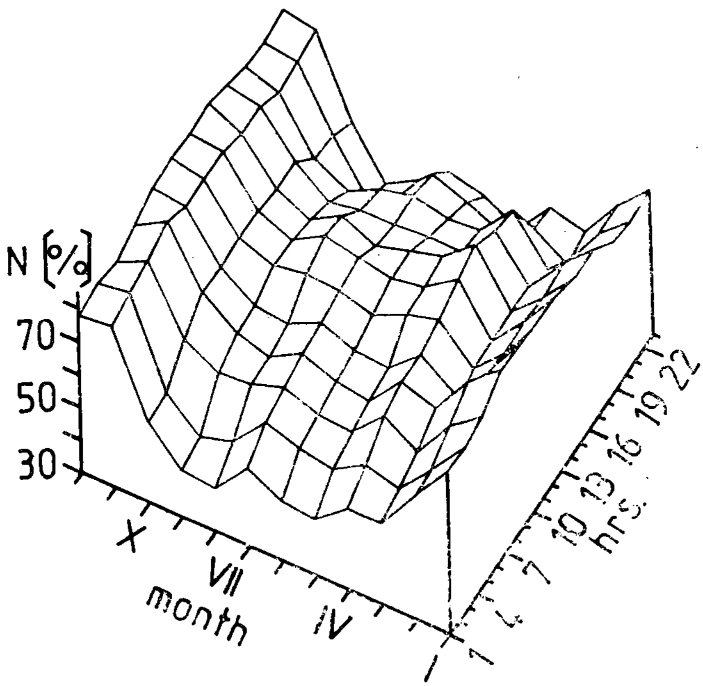

Fig. 1. Diurnal course of cloudiness (Warsaw 1956—1960)

case, the size of twenty four hours' amplitudes increases, and the time of the greatest cloudiness thifts to the afternoon.

The synoptic situation, and the kind of air mass in particular, play a major role in shaping the cloudiness. Throughout the whole year as well as within every twenty-four hours (except for the afternoons in December), a greater cloudiness can be observed in the case of the maritime polar air mass than in the case of the continental one (Fig. 2). Differences in the volume of cloudiness between those two types of air mass vary from around 10% to 40%, and they are usually bigger around noon, especially in Summer.

During Winter, twenty four hours' variations in cloudiness have a similar character in the case of both types of polar air mass. There is an increase in cloudiness in the morning (7—9 a.m.), and then around noon a slight fall follows. The values of mP oscillate around 80%—90% while those of cP — around 60%—80%. Also, twenty-four hours' amplitudes of the cloudiness volume are similar and they vary from 10% to 20%.

In all the other seasons, i.e. from Spring till Autumn, twenty-four hours' variations in the cloudiness volume of both types of polar air mass diverge. Still, however, greater twenty-four hours' variations in

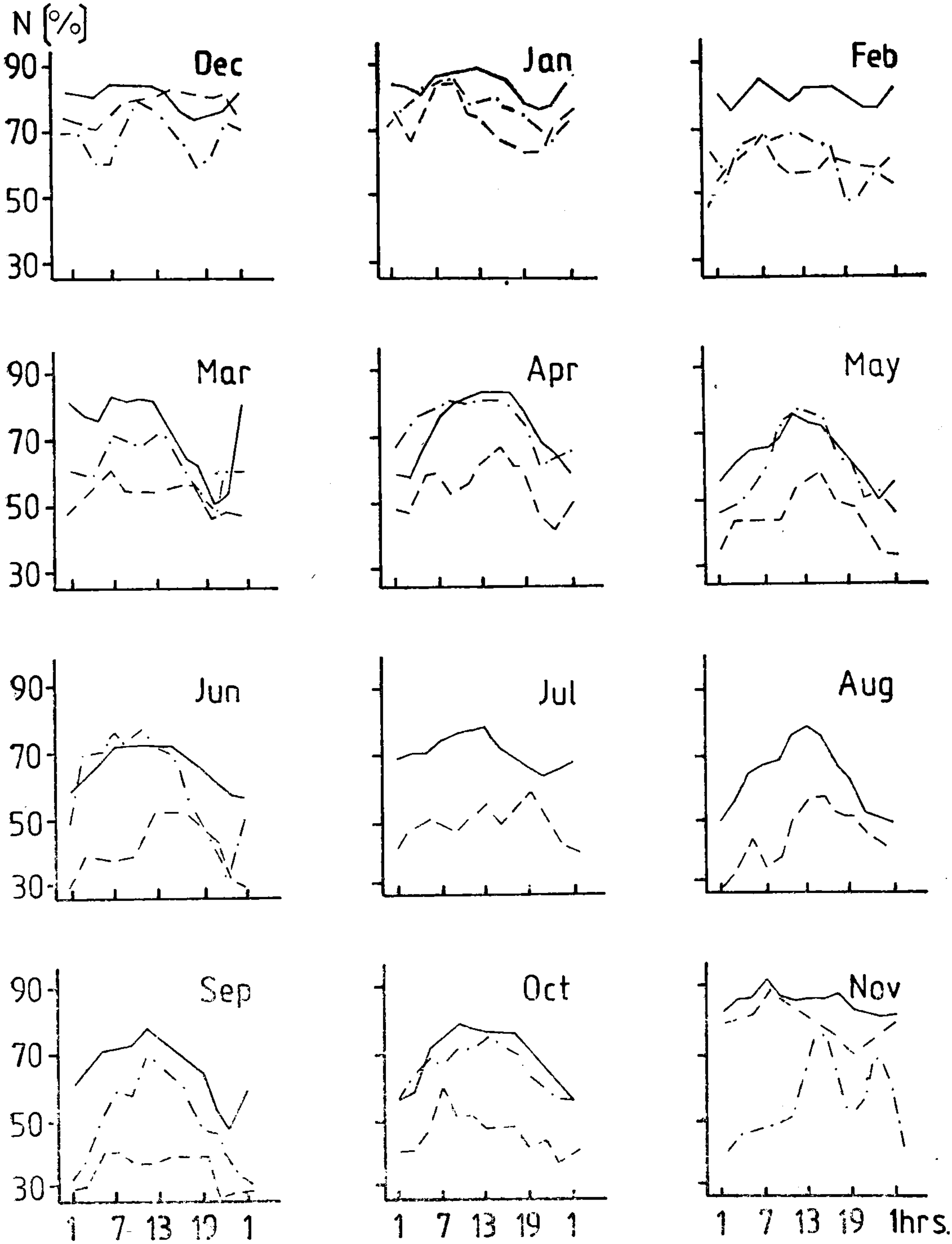

Fig. 2. Diurnal course of cloudiness in different air masses (Warsaw 1956—1960)
Legend: mP ——— cP — — — A —·—

cloudiness are characteristic of maritime air mass. But the character of these variations is different. In the case of mP, the course of change is simple: there is one minimum at night (9 p.m.—3 a.m.) and one maximum around noon (11 a.m. — 3. p.m.). In the case of continental polar air mass, on the other hand, the course of change within twenty-four hours turns out to be complex, i.e. the occurrence of the secondary maximum values can be observed. The lowest degree of twenty-four hours' cloudiness occurs at night (9 p.m. — 3 a.m.), and the highest — in the afternoon and in the evening (3—7 p.m.). Furthermore, cloudiness, having reached the minimum at night, slightly increases in the morning (5—9 a.m.), to lower again before noon. It seems that this character of twenty-four hours' variations in the cloudiness volume is caused by the fact that particular kinds of clouds in a given air mass appear with different frequencies (Warakomski 1969). uDring the warm season, in the maritime polar air mass the cumulous type of cloud is most frequent (Cumulus, Stratocumulus); the formation of this type of clouds is most intensive around noon and in the afternoon, which results in greater cloudiness. In the case of the continental polar air mass, one can most often observe high-altitude clouds (Cirrus) while the cumulous type of clouds (Cumulus) is less frequent.

When compared to the two types of polar air mass, the artic air mass differs depending on the season. In Winter, values of the cloudiness volume in A fall in between those characteristics of mP and cP. The artic air mass is characterized by the greatest cloudiness in the late Spring, especially in the morning and at noon. In November and December, on the other hand, this type of air mass has the lowest degree of cloudiness.

To capture the regularities of twenty-four hours' variations in cloudiness, the harmonic analysis has been applied:

$$n_i = n_o + n_1 \sin (A_1 + a) + n_2 \sin (A_2 + 2a) + n_3 + 3a) + n$$

where: n_i — cloudiness volume at i-hour,

— the mean twenty-four hours' cloudiness volume,

$n_1, n_2, ..., A_1, A_2, ...$ — constants searched for,

$a = \frac{360}{k} \cdot i$ — where k — the number of observations in twenty-four hours, i — an hour for which the value of the cloudiness volume is to be estimated.

Calculations of coefficients of those equations (Table 1) show what the character of twenty-four hours' variations in cloudiness is, but, at the same time, they also state what their value is every hour. The higher the value of coefficients, the greater variation is to be expected.

Table 1

Coefficients of equations of diurnal course of cloudiness. Warsaw 1956—1960.

month	avg.	n1	A1	n2	A2	n3	A3
without division into air masses							
I	80	5.5337	−40.1	0.6667	30.0	−1.7401	−73.3
II	70	4.0385	−28.5	2.0817	−46.1	−1.5366	−12.5
III	58	4.7661	−46.9	2.5000	−30.0	1.2019	−56.3
IV	67	9.6070	−87.3	4.0859	−28.0	0.3727	−63.4
V	58	10.2478	−85.2	2.6034	− 3.7	2.2669	−36.0
VI	59	7.2428	−84.9	2.1667	−30.0	1.5811	−71.6
VII	61	5.5404	−67.5	1.3229	−70.9	2.2423	−48.0
VIII	57	11.6505	−83.9	2.2423	−15.1	2.2669	−72.9
IX	55	11.8719	−68.7	2.9486	−38.4	0.0000	0.0
X	63	8.0594	−69.8	1.8028	−76.1	−1.1785	8.1
XI	80	3.8995	−17.7	0.0000	0.0	0.0000	0.0
XII	80	3.1716	−78.7	−1.2019	−76.1	−0.8975	−68.2
in mP air mass							
I	83	5.2972	−56.5	2.1794	66.6	−2.0069	−85.2
II	80	2.0531	−68.1	1.6915	−37.8	−2.0883	−28.6
III	72	12.9676	−23.7	5.4083	43.9	4.5031	51.0
IV	74	−12.4274	83.0	−2.6458	70.9	−1.6997	−11.3
V	65	10.6295	−71.6	2.7538	5.2	2.4267	−15.9
VI	66	7.4283	−67.9	1.5899	−63.0	0.0000	0.0
VII	68	7.6254	−49.0	1.3642	42.2	1.6750	5.7
VIII	60	14.1631	−74.0	2.8868	0.0	2.2361	−63.4
IX	66	12.7052	−54.7	4.7813	− 5.0	3.7602	12.8
X	70	10.3402	−78.6	4.1767	−86.0	−1.0541	18.4
XI	84	3.5882	−33.4	1.8028	−43.9	−1.1785	−81.9
XII	80	4.8219	−19.6	2.4552	79.8	−0.5270	−71.6
in cP air mass							
I	73	8.3091	− 8.2	−2.9297	− 9.8	−3.6056	−33.7
II	59	1.6628	12.7	3.9405	−68.5	−1.4240	20.6
III	53	4.3951	−58.1	3.6553	−50.8	−0.8333	−36.9
IV	56	−8.2213	82.9	6.0069	−27.2	−0.6009	56.3
V	47	−9.1771	76.7	3.6094	− 1.3	3.0596	−60.6
VI	42	−9.5144	62.2	3.6553	−18.6	3.2361	−55.5
VII	47	−3.7553	56.5	2.8916	−63.3	3.8909	−46.7
VIII	42	−11.0313	59.0	1.1547	0.0	4.8362	−88.0
IX	35	5.7698	−74.3	3.7231	−45.7	−0.8975	−21.8
X	46	6.7221	−49.2	3.2532	−87.5	−1.6997	−11.3
XI	78	7.0251	−12.3	−1.0929	−22.4	−1.5723	−32.00
XII	79	−4.8250	38.6	−1.6415	−14.7	−0.7071	−45.0

ctd. Table 1

month	avg.	n1	A1	n2	A2	n3	A3
in A air mass							
I	76	6.5244	−33.1	2.8431	−44.7	−0.8333	−53.1
II	61	7.9992	−36.2	2.2048	70.9	−2.8333	−28.1
III	63	6.6356	−49.2	−3.1929	−66.0	−5.7855	−11.6
IV	76	8.8904	−64 5	3.7859	− 7.6	1.0672	51.3
V	61	14.7204	−88.7	−2.1667	−57.8	0.0000	0.0
VI	60	18.8041	−42.5	8.3782	− 2.3	4.2492	−25.6
IX	51	16.4631	−76.0	1.4814	−73.0	−3.2361	78.1
X	66	8.0986	−72.3	2.4661	− 5.8	1.0541	−71.6
XI	55	−11.4969	47.0	−6.9602	−65.5	−8.6923	57.5
XII	68	4.0958	−71.4	−7.7262	−68.1	1.6750	84.3

Table 2

Frequency (%) of fair and cloudy days in the different air masses. Warsaw 1956—1960.

month	fair days			cloudy days		
	mP	cP	A	mP	cP	A
I	0.0	10.3	0.0	62.3	55.2	47.4
II	0.0	20.0	0.0	58.0	40.0	33.3
III	0.0	17.6	0.0	50.0	28.7	40.0
IV	0.0	10.5	0.0	60.9	26.3	45.4
V	3.6	6.0	0.0	30.4	14.0	33.3
VI	4.2	7.7	0.0	33.8	5.1	0.0
VII	1.1	18.4	—	39.8	5.9	—
VIII	0.0	11.8	—	24.2	2.9	—
IX	0.0	31.4	4.8	31.7	14.3	14.3
X	0.0	23.1	5.9	46.0	17.9	29.4
XI	0.0	3.3	0.0	69.2	53.3	0.0
XII	3.1	7.7	0.0	47.7	63.5	22.2

Our remarks on variations in cloudiness of particular types of air mass confirm the observations on the frequency of fairy and cloudy days occurrence (Table 2). The highest number of fairy days (the mean twenty-four hours' cloudiness below 20%) can be noted in the case of cP, in Autumn and in Winter in particular. On the other hand, for mP and A, the days of this type are to be observed very infrequently. Cloudy days (the mean twenty-four hours' cloudiness above 80%) are most typical of maritime polar air mass, and they characterize a colder part of the year, in particular. At that time of the year, cloudy days also appear in the case of cP as well as A. Throughout Summer, in the latter two types of air mass the frequency of occurrence of cloudy days is at its minimum.

Summing up, the greatest cloudiness for each type of air mass was observed in Winter. In Spring and in Summer, the highest values of the cloudiness volume were correlated with the maritime polar air mass and the arctic air mass. Throughout the whole year, the lowest degree of cloudiness was observed when the flow of continental polar air mass occurred. This air mass is characterized by the highest coefficient of high-altitude clouds (Cirrus), and the clouds of this kind have little effect on the cloudiness volume (Warakomski 1969). Therefore, in the case of the continental type of air mass, the greatest number of fairy days could be noted.

It seems that the present results could be helpful in forecasting the cloudiness volume for a given type of air mass.

REFERENCE

Warakomski, W., 1969, *Zachmurzenie i rodzaj chmur w zależności od mas powietrza w Polsce* (Cloudiness and cloud types depending on the kind of air mass in Poland), Lublin, UMCS.