CUMULONIMBUS CLOUDS AND RELATED WEATHER PHENOMENA AT TÂRGU-MUREŞ, ROMANIA

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ABSTRACT. Cumulonimbus clouds and related weather phenomena at Târgu Mureş, Romania. Cumulonimbus (Cb) is a vertically developed cloud, associated with some several weather phenomena, such as hail. Yearly (and in some cases monthly) meteorological data from the period 1971-2005 registered at the Târgu-Mureş weather station (lat. 46°32', lon. 24°32', elevation 308 m) were studied. However, Altocumulus (relative frequency = 25%) and Stratocumulus (14%) are the most frequently clouds, in summer the presence of Cumulonimbus cloud is remarkable (18%). Mann-Kendall trend analysis and Sen's slope estimate (Q) show positive and statistically significant trend as regards number of Cumulonimbus clouds (Q=6.458), number of days with rain shower (Q=1.000), number of days with snow shower (Q=0.250) and a decreasing, statistically significant trend in the case of the number of days with hail (Q=-0.043) and number of days with thunderstorm (Q=-0.211). Moreover, monthly number of Cb also indicate an increasing, statistically significant trend in all 12 cases. The Pearson correlation coefficient (r) is statistically significant between the number of Cb and the number of days with rain shower (r=0.827) respectively the number of Cb and the number of days with rain shower (r=0.541). Daily amount of precipitations exceeded 30 mm were registered mainly in summer. They are almost related to Cumulonimbus clouds and rain showers, and they occur most frequently during the presence of TRM (Trough over Central Europe), WZ (Cyclonic Westerly) and BM (Zonal Ridge across Central Europe) synoptic situations (Hess-Brezowsky classification).

Keywords: Cumulonimbus, Târgu-Mureş, showers, hail, thunderstorm

1. INTRODUCTION

Cumulonimbus are vertically developed, dense and massive clouds, with a form of a mountain. They have a mixed composition, and insides them there are strong vertical currents. Often, they represent the continuing development of Cumulus congestus clouds. In case of accentuated instability they can be formed by the evolution of Altocumulus castellanus clouds. Their identification may be difficult when they overlay all the sky. Two species are known: *calvus* and *capillatus*. Cumulonimbus calvus (Fig. 1) haven't any fibrous parts, while the upper part of Cumulonimbus capillatus (Fig. 2) is striated, fibrous and in a shape of an anvil.

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Fig. 1. Cumulonimbus calvus

Fig. 2. Cumulonimbus capillatus

The followed meteorological data were collected from Târgu-Mureş weather station (lat. 46°32', long. 24°32', elevation 308 m) from period 1971-2005: yearly and monthly number of Cumulonimbus clouds, yearly and seasonal number of all 9 cloud types, yearly number of days with rain shower, snow shower, hail and thunderstorm.

Some statistical characteristics of studied elements are presented in Table 1.

Table 1. Statistical characteristics of number of Cumulonimbus, number of days with rain shower, snow shower, hail and thunderstorms

number of day with:	Cumulonimbus (at 00, 06, 12, 18 UTC)	rain shower	snow shower	hail	thunderstorm
mean	207	82	7	1	41
standard deviation	71.3	13.8	4.3	1.3	7.8
maximum	362 (2001)	106 (1995)	16 (1995)	4 (1980, 1983)	68 (1975)
minimum	86 (1976)	57 (1971)	0 (1972)	0 (several years)	27 (2005)

2. RELATIVE FREQUENCIES OF CLOUDS

Relative frequencies of clouds were calculated based upon on the values of the four main time of observations (00, 06, 12, 18 UTC), including cases where the sky is clear and also sky invisible (fog).

Table 2. The relative frequencies of clouds (annual and summer values)

Relative frequencies (%)	**Ci**	**CC**	**Cs**	**Ac**	**As**	**Ns**	**Sc**	**St**	**Cu**	**Cb**	**Ξ**	**0**
annual	10.0	0.1	1.8	25.1	6.3	2.9	14.1	2.6	9.9	**10.3**	2.7	14.1
summer	10.4	0.1	1.1	26.1	2.5	1.1	9.1	0.8	15.7	**18.2**	0.5	14.3

However, Altocumulus and Stratocumulus are most the most frequently clouds (with 25% and respectively 14%), in summer the relative frequency of Cumulonimbus is noticeable (18 %) (Table 2, Fig. 1)

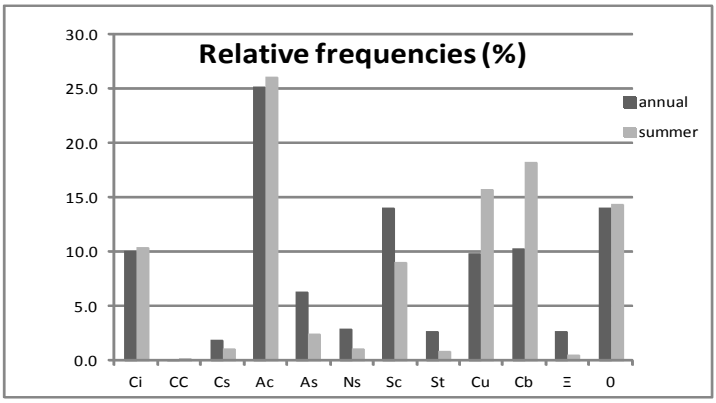

Fig. 1. The relative frequencies (%) of cloud (annual and summer values)

3. LINEAR TREND ANALYSIS

Mann-Kendall trend analysis (Mann, 1945; Kendall, 1975) was applied in order to analyze the linear trend, and Sen's slope estimate (Sen, 1968) was calculated to determine the rate of the trends, using Makesens software (Salmi et al., 2002).

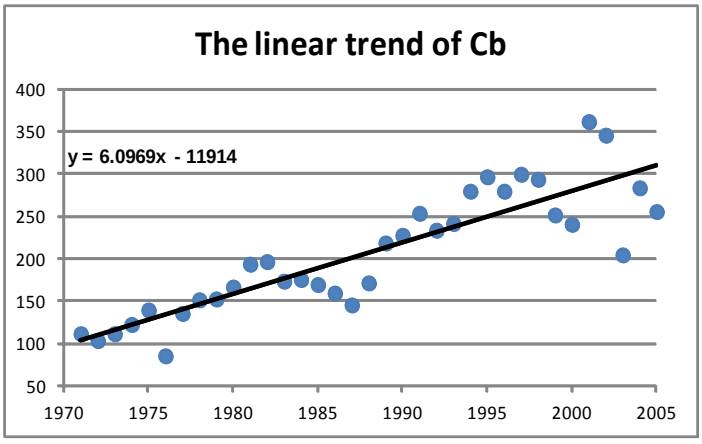

Fig. 2. The linear trend of Cumulonimbus (annual data)

Linear trend of Cumulonimbus in all 13 cases (annual and monthly values) is statistically significant and increasing (Fig. 2., Table 3).

Table 3. Linear trend of Cumulonimbus (Mann-Kendall test and Sen's slope estimate). All values are statistically significant, at levels: ***=0. 001, **=0. 01, *=0. 05

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.087**	0.111*	0.579***	1***	0.733***	0.4**	0.857***	0.636**	0.625***	0.424**	0.286***	0.083**	6.458***

Also positive and statistically significant trend is characteristic is case of number of days with rain shower and snow shower. As regarding number of days with thunderstorm and hail, decreasing trends were detected (Table 4)

Table 4. Linear trend of number of days with thunderstorm, hail, rain shower and snow shower. All values are statistically significant, at levels: ***=0.001, *=0.05

thunderstorm	hail	rain shower	snow shower
-0.211*	-0.043*	1.000***	0.25***

Rain showers and snow showers begins and ends abruptly, their intensity changes rapidly (sometimes this change is violent); generally they have short duration, and they can result high amounts of precipitations. Therefore, the positive trend of theses elements may lead to increasing amounts of precipitation at one time.

4. CORRELATION ANALYSIS

The Pearson correlation coefficient was calculated between the yearly number of Cumulonimbus, number of days with thunderstorm, hail, rain shower and snow shower.

Table 5. Pearson coefficient between the yearly number of Cumulonimbus, number of days with thunderstorm, hail, rain shower and snow shower (statistically significant values are marked with bold)

	Cumulonimbus	Thunderstorme	Hail	Rain shower	Snow shower
Cumulonimbus	0				
Thunderstorme	-0.224	0			
Hail	-0.287	0.213	0		
Rain shower	**0.827**	0.064	-0.102	0	
Snow shower	**0.541**	-0.062	-0.101	0.4	0

The Pearson correlation coefficient (r) is statistically significant between the number of Cumulonimbus and the number of days with rain shower (r=0.827) respectively the number of the Cumulonimbus and the number of days with rain shower (r=0.541). But there is no correlation between the Cumulonimbus and the number of days with thunderstorm and respectively the number of days with hail (Table 5).

5. DAILY AMOUNT OF PRECIPITATION EXCEEDED 30 MM

Daily amount of precipitations exceeded 30 mm were registered mainly in summer (of all 42 cases, 8 were registered in June, 15 in July and 12 in August). They are almost related to Cumulonimbus clouds and rain showers. The highest value (67.8 mm) from 2 July 1975 were due to a rain shower with a very high intensity, accompanied by thunderstorms (with a number of lightning equal to 289). This high amount of precipitation contributed to one of the largest floods of the twentieth century in the region.

Daily amount of precipitations exceeded 30 mm occur most frequently during the presence of TRM (Trough over Central Europe), WZ (Cyclonic Westerly) and BM (Zonal Ridge across Central Europe) synoptic situation, after Hess-Brezowsky classification. (Werner & Gerstengarbe, 2010), (Table 6). TRM and WZ are cyclonic situations, while BM is an anticyclonic circulation type. The presence of Cumulonimbus and associated high amount of precipitation in the presence of an anticyclonic situation seems less plausible, but such situations were described in the southern part of Romania. In these situations the presence of a stationary front over the region is responsible for high amount of 1-day precipitation (Cazacioc, 2007).

Table 6. Frequency of daily amount of precipitations exceeded 30 mm in the case of different synoptic situations (Hess-Brezowsky)

Synoptic situation (Hess-Brezowsky)	**Frequency**
Icelandic high, Trough over Europe HNZ	1
Scandinavian High, Ridge over Central Europe HFA	3
U Undetermined	2
Trough over Central Europe TRM	6
Cyclonic Westerly WZ	6
Cyclonic North-Easterly NEZ	2
Cyclonic Northerly NZ	1
Anticyclonic North-Westerly NWA	2
Anticyclonic South-Westerly SWA	2
South-Shifted Westerly WS	2
Anticyclonic Westerly WA	2
High over Scandinavia-Iceland, Trough over Central EuropeHNFZ	1
High over Scandinavia-Iceland, Ridge over Central Europe HNFA	1
Anticyclonic Southerly SA	1
Zonal Ridge across Central Europe BM	6
High over the British Isles HB	1
Cyclonic North-Westerly NWZ	1
High over Central Europe HM	1
Trough over Western Europe TRW	1
Scandinavian High, Ridge over Central Europe HFA	1

6. CONCLUSIONS

At Târgu Mures weather station Cumulonimbus clouds are most frequently in summer (with relative frequency equal to 18%). Positive and statistically significant trend (Mann-Kendall test, Sen's slope estimate) were detected in the case of the number of Cumulonimbus (yearly and monthly values), number of days with rain shower and number of days with snow shower, respectively decreasing, statistically significant trend in the case of number of days with hail and number of days with thunderstorm. The Pearson correlation coefficient is statistically significant between the number of Cb and the number of days with rain shower respectively the number of Cb and the number of days with rain shower. Daily amount of precipitations exceeded 30 mm were registered mainly in summer, and they are almost related to Cumulonimbus clouds and rain showers. They occur most frequently during the presence of a cyclonic situation (eg. TRM - Trough over Central Europe or WZ - Cyclonic Westerly), but as well they may be caused by anticyclonic circulation patterns (eg. BM-Zonal Ridge across Central Europe) (Hess-Brezowsky classification). It mentioned that the highest 1-day precipitation amount (at 2 July 1975, which causes a major flood) were due to an extremely intense rain shower with a thunderstorm. This also indicates the importance of the increasing trend as regard number of days with rain shower.

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