SOME CHARACTERISTICS OF MAXIMUM ANNUAL AND SEASONAL QUANTITIES OF RAINFALL REGISTERED IN 24 HOURS IN ROMANIA

Lecturer Dr. Traian Tudose[1]

Assoc. Prof. Dr. Adina-Eliza Croitoru[1]

PhD Student Gabriela Victoria Harpa[1]

Master Student Sabina Andreea Scripcă[1]

[1]"Babeş-Bolyai" University, Faculty of Geography, **Romania**

ABSTRACT

The paper analyzes some characteristics of annual and seasonal amounts of rainfall recorded in 24 hours in Romania. Annual and seasonal frequency distribution of rainfall quantities registered in 24 hours, air circulation type regarding these events, and the return periods of the absolute maximum values have been analyzed.

Annual and seasonal values of maximum 24-hour precipitation amount from 23 weather stations from Romania, located between 3 and 661 m, have been considered over a period of 55 years (1961-2015). First, the data sets were tested using homogeneity distribution test at 99 % of significance level provided by XLSTAT software. HYFRAN software and HYSPLIT model have been employed in order to calculate statistics based on frequency analysis and to identify the atmospheric circulation type, respectively.

The main findings are: absolute maximum annual rainfall quantities vary between 65.3 and 224.0 mm, with the highest values (over 120 mm) in the east and south-east part of the country; most of the weather stations have the highest annual frequency between 25-50 mm, while winter, spring, and autumn are characterized by high frequency of 0-25 mm amounts; for the winter season, the maximum 24-hour precipitation has never exceeded 75 mm, in spring and autumn they are under the 125 mm threshold, while in summer locally exceeded 200 mm; the return periods of maximum annual quantities of rainfall are generally ranging between 32.2 and 387 years, highlighting the continental climate of some regions of the country; four types of air circulation have been detected, more frequent from south and southwest part of the Europe, bringing warm and moist air masses.

Keywords: rainfall, return period, air circulation, Romania.

INTRODUCTON

High rainfall fallen in a short time can produce negative effects on environment and society, especially through flash floods. The amount of precipitation fallen over an area can be analyzed at different time scale: one-hour, 3, 12, 24, 48, and 72 hours. The genesis of rainfalls up to 24 hours are influenced by the spatial and mesoscale conditions of the environment, while synoptic conditions become more important in the case of rainfalls lasting more than 24 hours. Because of this situation, 24-hour precipitation amount allows better the identification of synoptic conditions of rainfalls and their frequency analysis [1].

Frequency analysis of different rainfall amounts permits calculation of probability of occurrence, as well as the statistical probability of recording higher values [2]. These characteristics are useful to identify the areas in which high quantities of precipitation may occur and produce local floods. Under these circumstances, the identification of synoptic configurations causing severe weather phenomena is particularly important for good quality and high resolution weather forecasts.

The present study is dedicated to the frequency analyses of annual maximum 24-hour precipitation amounts and to the synoptic conditions generating them, as well as to the spatial and seasonal distribution of their occurrence.

DATA AND METHODS

The present study uses annual and seasonal maximum 24-hour precipitation amount derived from non-blended daily precipitation data sets from European Climate Assessment&Dataset [3], recorded in 23 weather stations in Romania (fig. 1), over a 55-year period (1961-2015). Missing data were filled in from row Synop messages, available in Meteomanz data base (www.meteomanz.com). The weather stations are located at altitudes between 3 and 661 m (table 1). Annual maximum 24-hour precipitation amount represents the highest amount of precipitation recorded in 24 hours in a year, while seasonal maximum 24-hour precipitation amount is given by the highest amount of precipitation recorded in 24 hours in a specified season of the year.

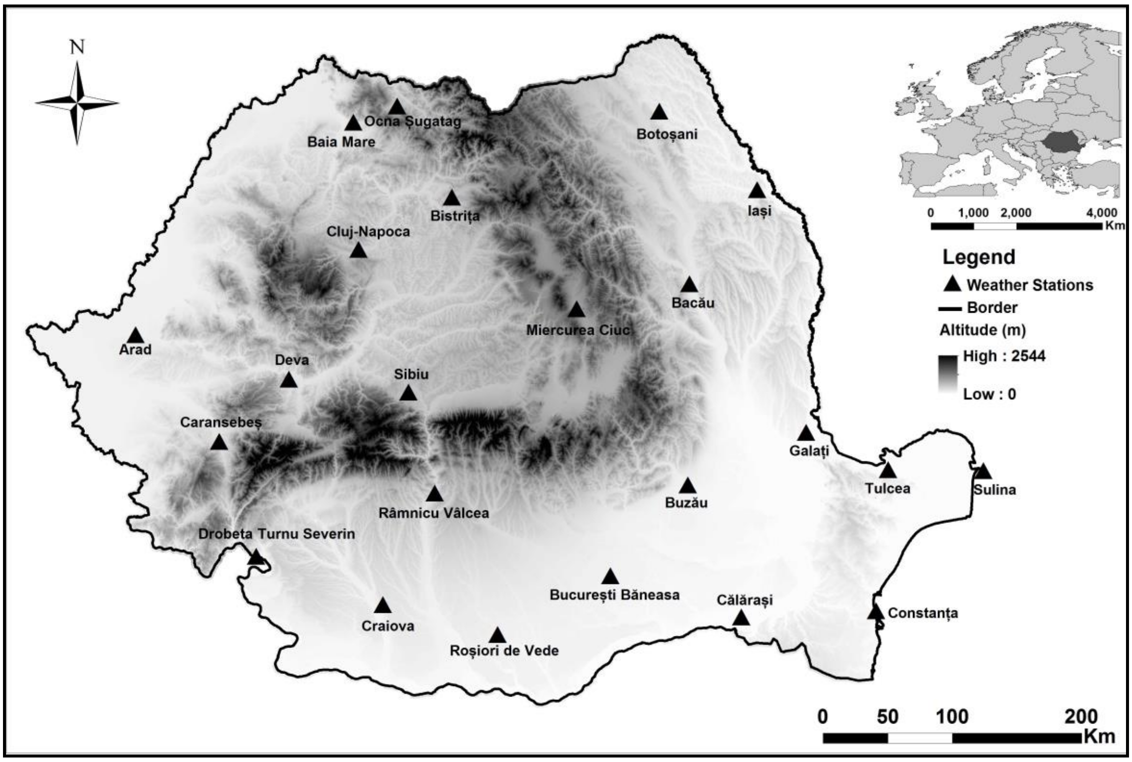

Fig. 1. Weather stations location in Romania

For the common period 1961-2015, a series of 55 annual maximum values and 220 seasonal maximum values (55 for each season) for each of the 23 weather stations were analyzed. Taking into account the weather stations position, they were grouped as it fallows: west part of the country (Caransebeş and Arad), central part (Baia Mare, Ocna Şugatag, Bistriţa, Cluj-Napoca, Miercurea Ciuc, Deva, and Sibiu), east part (Botoşani, Iaşi, Bacău, and Galaţi), southeast part (Tulcea, Sulina, and Constanţa), and south part of the country (Râmnicu Vâlcea, Buzău, Drobeta Turnu Severin, Bucharest Băneasa, Craiova, Calăraşi, and Roşiorii de Vede) (fig. 1).

First, the data sets were tested using trend and homogeneity distribution test at 0.01 significance level provided by XLSTAT software, developed based on the methodology described by Wijngaard et al. [4]. The statistical test revealed that there is no trend in the time series and they are sufficiently homogeneous for the analysis. The lack of trend allowed further analysis of probability.

The probability curve and return period of minimum and maximum annual 24-hour precipitation amount was done using HYFRAN software [2]. For this purpose, a set of statistical tests were conducted to determine whether the data series are independent and identically distributed: Wald-Wolfowitz test for independence, Kendall stationarity test, and Wilcoxon homogeneity test at annual scale. The chosen significance level was 0.05. After that, the probability distribution was analyzed in order to determine which of those tests describe best the variation of the annual rainfall amounts registered in 24 hours.

In order to identify the equation that describes best the variation, spatial homogeneity (presence of the same type of variation at the neighboring stations) and numerical criteria as AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion) and adequacy Chi-squared test were employed.

Statistical analysis of the 23 data series of annual maximum 24-hour precipitation amount revealed that probability functions that best describe the variation are Gumbel (1), Log-Pearson type III (2) and Lognormal (3):

$$f(x) = \frac{1}{\alpha}\exp\left[-\frac{x-u}{\alpha} - \exp\left(-\frac{x-u}{\alpha}\right)\right] \quad (1);$$

$$f(x) = \frac{\alpha^{\lambda}}{x\Gamma(\lambda)}(\ln x - m)^{\lambda-1} e^{-\alpha(\ln x - m)} \quad (2);$$

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}}\exp\left\{-\frac{[\ln x-\mu]^2}{2\sigma^2}\right\} \quad (3).$$

Where:

$\alpha, \lambda, m, \sigma, \mu, u -$ Estimated parameters

Exceedance probability and return period are defined by:

$$T = \frac{1}{1-q} = \frac{1}{p} \quad (4)$$

Where:

q- Probability of no exceedance in a period of time;

p – Probability of exceedance in a period of time;

T – Return period.

To establish the atmospheric circulation type for each annual maximum 24-hour precipitation amount case, HYSPLIT model was used [5]. A simple air parcel 48-hour backward trajectory option was used in order to identify the direction of the influx and the origin of the air masses in the studied area [6]. Based on weather maps provided by wetter.3de archive [7], temperature and geopotential at 500, 700, 850 hPa levels, moisture at 700 hPa level and sea level pressure were analyzed. Finally, four atmospheric circulation types were derived.

The frequency of the annual and seasonal maximum 24-hour precipitation amount was determined by dividing them into six classes (less than 25 mm, 25-50 mm, 50-75 mm, 75 -100 mm, 100 - 125 mm, and over 125 mm).

RESULTS AND DISCUSIONS

Absolute annual maximum 24-hour precipitation amount varies between 65.3 mm (Deva) and 224.0 mm (Drobeta Tr. Severin). The lowest quantities were registered in the Western and Central Romania (generally, under 100 mm), and the highest in east and southeast part of the country (table 1). Seasonally, the highest values are recorded during summer and spring, while in the winter they are often below 50 mm. Moreover, none of the weather stations recorded any absolute annual maximum 24-hour precipitation in winter (table 1). The highest annual frequency was observed in the case of class 25-50 mm, except Sulina weather station (which recorded less than 25 mm), followed by 50-75 mm class. The two classes summarize 69.1% to 94.6% respectively, while cases of precipitation amount greater than 75 mm have a lower frequency (below 10 %).

Seasonally, winter, spring, and autumn are characterized by high frequency of 0-25 mm class, while in summer most cases of maximum rainfall quantities are in the class of 25-50 mm. Moreover, the highest amounts of precipitation fallen in 24 hours in winter has never exceeded 75 mm, in spring and autumn they are under the 125 mm, while in summer locally exceeds 200 mm.

Using the distribution of the three probability functions and their coefficients, the return periods of different values of maximum rainfall quantities registered in 24 hours (*T*), and the probability of not exceeding (*q*) was determined. It has been noted that regression function describing best the annual variation for western and central part of the country is Gumbel, for the east and southeast of Romania is Log-Pearson type III, while for the south part of the country is Log-normal.

The return period of the absolute minimum rainfall quantities fallen in 24 hours are between 1.0002 and 1.032 years, which correspond to an annual probability of not exceeding between 0.02 and 3.1% (table 2). In the case of the return period for the absolute maximum amounts, the extreme values are between 37 and 387 years and the annual probability of not exceeding is between 97.3 and 99.74 %. It stands out the uneven spatial distribution, and the return periods over 300 years are present in the eastern part of the country.

Table 1. Absolut seasonal and annual maximum rainfall quantities fallen in 24 hrs.

Weather station	Height (m)	Spring (mm)	Summer (mm)	Autumn (mm)	Winter (mm)	Annual (mm)
Arad	116	56.6	71.0	55.4	32.3	71.0
Caransebeş	241	67.8	92.4	54.8	38.8	92.4
Baia Mare	216	121.4*	71.8	77.4	51.4	121.4
Ocna Şugatag	503	46.3	81.8	82.2	41.8	82.2
Bistriţa	366	72.3	61.0	50.6	32.0	72.3
Cluj-Napoca	410	49.5	81.6	51.7	37.5	81.6
Deva	240	65.3	64.2	40.3	33.0	65.3
Miercurea Ciuc	661	50.2	76.0	52.3	57.4	76.0
Sibiu	443	69.9	70.4	53.4	39.0	70.4
Bacău	184	58.4	119.0	94.7	27.4	119.0
Botoşani	161	68.4	81.2	63.4	42.3	81.2
Galaţi	69	83.3	126.2	113.3	42.7	126.2
Iaşi	102	68.2	136.7	107.9	42.7	136.7
Tulcea	4	51.6	134.5	66.6	55.0	134.5
Constanţa	13	61.2	201.0	112.4	59.4	201.0
Sulina	3	70.0	55.0	84.9	50.5	84.9
Călăraşi	19	84.0	81.0	80.8	69.4	84.0
Bucharest-Băneasa	90	61.9	85.1	126.4	55.8	126.4
Buzău	97	90.5	76.5	69.2	37.4	90.5
Craiova	192	77.6	84.8	81.0	53.8	84.8
Drobeta Tr. Severin	77	70.3	224.0	118.8	60.3	224.0
Râmicu Vâlcea	237	122.3	97.8	83.2	46.1	122.3
Roşiori de Vede	102	53.6	82.6	45.4	38.8	82.6

Eight trajectories of air influx were found, and based on their characteristics were reclassified into 4 atmospheric types: Type 1: southern and southwestern influx, Type 2 – western influx, Type 3 – northern and northwestern influx, and Type 4 – eastern, southeastern, and northeastern influx. This allowed the identification of synoptic conditions that generated the annual and seasonal maximum 24-hour precipitation amount for each event. Air influx and synoptic configuration analyses led to the identification of some particular features of each atmospheric type. Thus, Type 1 is characterized by the presence of the front side of an upper-air trough that favors warm and humid air advection from Southern or South-western Europe; at the ground level, a low pressure area or an atmospheric depression is present. Type 2 is represented by a wide upper-air trough or a "cut-off" low and a low pressure area or a Mediterranean cyclone at the ground level. In the case of Type 3, the presence of the rear side of a deep upper-air trough or a "cut-off" low is observed; at the ground level, a low pressure area or a cold atmospheric front is present. For Type 4, the existence of an upper "cut-off" low and an eastern air circulation at the ground level was found.

Atmospheric circulation type and air mases analyses for the entire period revealed the existence of 898 days with annual maximum 24-hour precipitation amount for the studied weather stations. In 73.5% of the cases such high quantities of precipitation were recorded at one weather station per day; the frequency is decreasing with the increase of number of weather station per day; the lowest frequency was registered in the case of 9 weather stations that registered the annual maximum 24-hour precipitation in the same day and the same year (0.1%).

Table 2. The return period of absolute maximum and minimum rainfall quantities registered in 24 hours and the probability of not exceeding

Weather station	Return period (Min., Max.) and probability of not exceeding (q)			
	Min. (yrs.)	q (%)	Max. (yrs.)	q (%)
Arad	1.013	1.28	56.0	98.21
Caransebeş	1.0056	0.56	122.0	99.18
Baia Mare	1.0024	0.24	279.5	99.64
Ocna Şugatag	1.0168	1.65	65.5	98.47
Bistriţa	1.023	2.25	124.0	99.19
Cluj-Napoca	1.0065	0.65	91.5	98.91
Deva	1.008	0.79	87.0	98.85
Miercurea Ciuc	1.0175	1.72	155.0	99.35
Sibiu	1.0038	0.38	37.0	97.30
Bacău	1.0042	0.42	83.0	98.80
Botoşani	1.0051	0.51	71.0	98.59
Galaţi	1.0002	0.02	90.2	98.89
Iaşi	1.0101	1.00	64.8	98.46
Tulcea	1.02	1.96	387.0	99.74
Constanţa	1.024	2.34	351.0	99.72
Sulina	1.019	1.86	62.0	98.39
Călăraşi	1.025	2.44	51.0	98.04
Bucharest-Băneasa	1.0075	0.74	122.0	99.18
Buzău	1.0094	0.93	172.0	99.42
Craiova	1.032	3.10	41.1	97.57
Drobeta Tr. Severin	1.001	1.00	192.0	99.48
Râmicu Vâlcea	1.0085	0.84	102.0	99.02
Roşiori de Vede	1.0099	0.98	65.5	98.47

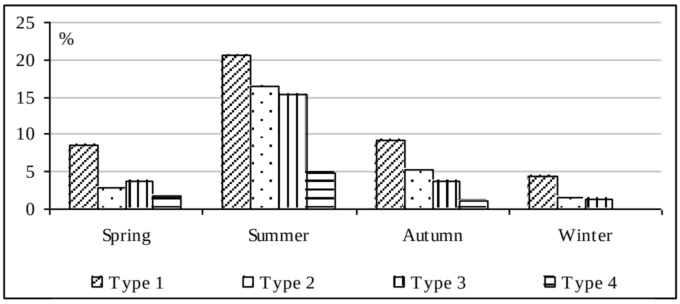

Fig. 2. Seasonal frequency of the 4 types of air circulation

The highest seasonal frequency of all types of air circulation is in summer (fig. 2), when more than half of the number of cases with maximum annual 24-hour precipitation is recorded. For summer, the highest rainfall quantities are generated by the warm and humid air advection (Type 1), air instability due to thermal convection (Type 2) and the presence of cold fronts coming from the Northern and Northwestern Europe (Type 3). The rest of the seasons are characterized by low frequencies of the four circulation types, but it stands out Type 1, especially for spring and summer, determined by warm and moist air advection through the Mediterranean cyclones.

The highest annual average frequency of air circulation is recorded in the case of Type 1 (42.2%), generated by influx form Southern and Southwestern Europe (fig. 3a); Type 2, characterized by western air circulation (fig. 3b) has an annual frequency of 25.5% and plays an important role in high moisture advection; Type 3 generates cold air advection from the northern and northwestern part of the continent (fig. 3c) and has an annual frequency of 23.7%; Type 4 has the lowest annual frequency (7.4%) and is characterized by the air movement from the eastern part of the continent (fig. 3d).

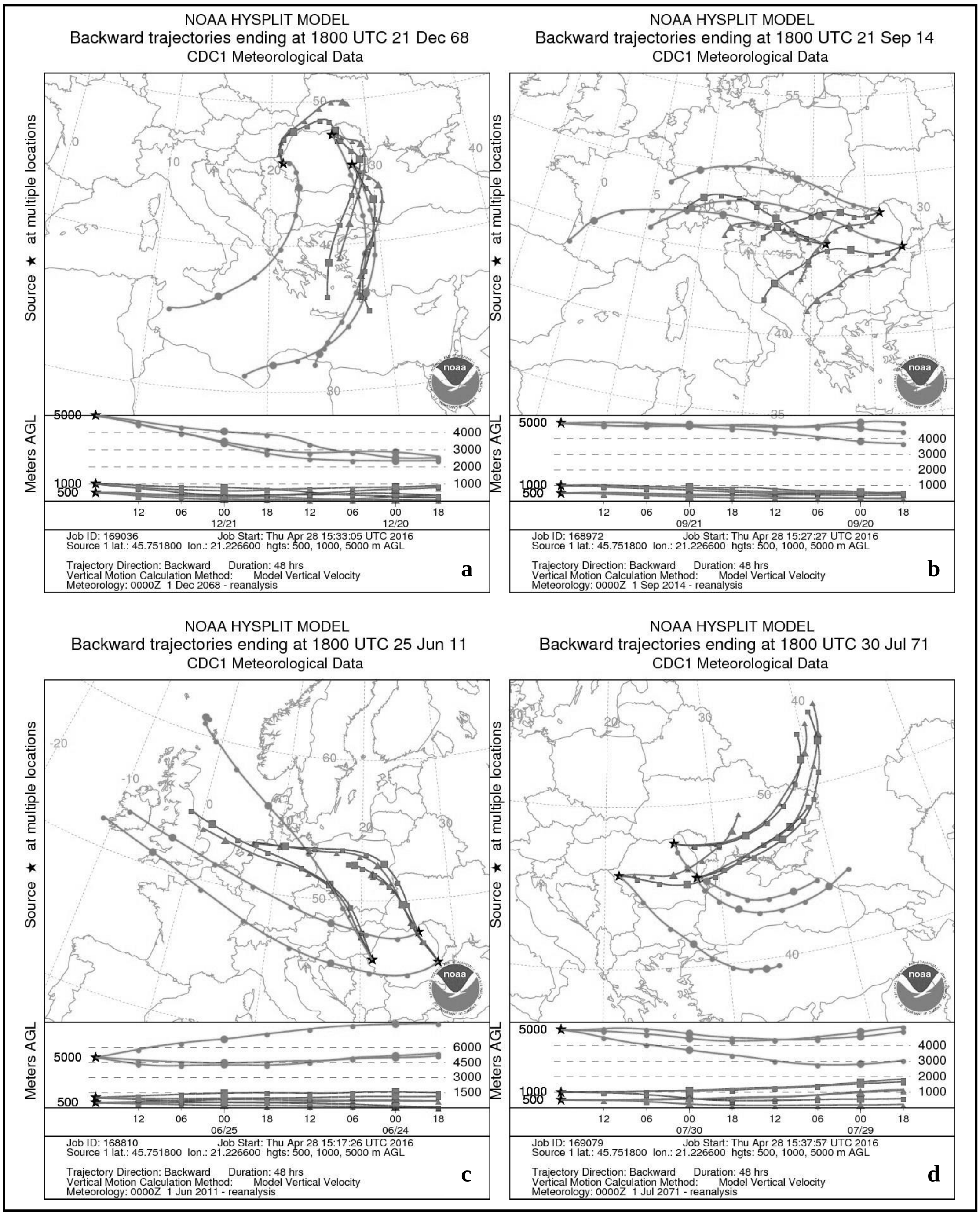

Fig. 3. The backward trajectories computed for each type (Type 1 – a, Type 2 – b, Type 3 – c, Type 4 - d).

CONCLUSIONS

Annual maximum 24-hour precipitation amounts have the lowest values in the Western and Central Romania, and the highest in the east and southeast of the country. The highest seasonal quantities of precipitation occur in summer and autumn, while in winter, they have never exceeded 50 mm. It can be noted the high frequency of 25-50 mm class, most often recorded in summer, while in winter and spring they are often under 25 mm; values over 125 mm are recorded only in summer.

The return period of the absolute annual minimum rainfall quantities fallen in 24 hours occurs yearly, with a probability of not exceeding less than 3.1%; the return period for the absolute annual maximum rainfall quantities is between 37 and 387 years; the values over 300 years were calculated for Southeastern Romania.

Type 1 of atmospheric circulation generating warm and moist air advection has the highest seasonal frequency (up to 20.6% in summer); Type 3 has the highest frequency in summer (15.4%) and generates cold air advection associated with cold atmospheric fronts; Type 2 has a similar seasonal distribution with less importance in spring, and Type 4 has the highest frequency in summer (4.8%), missing during winter.

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