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EARTH PHYSICS

SYNOPTIC CONTEXT OF FLOODS AND MAJOR FLASH FLOODS IN ROMANIA DURING 1948–1995*

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Abstract. The synoptic context has been studied in which events of floods and major flash floods have occurred and have been documented in Romania, between 1948 and 1995. The method was to identify the general circulation of air over Europe, in Hess-Brezowsky typology, and the general circulation over Romania in each of the cases. We present simple statistics based on the information about each event, and a subjective model of identifying the potentially hazardous synoptic contexts that were previously related to severe hydrological events in Romania.

Key words: floods, flash floods, Grosswetterlagen, circulation, statistics.

1. INTRODUCTION

During 1941 and 1943, at the former Institute for Long-Term Forecast in Bad Homburg (Germany), under the leadership of F. Baur, there has been conceived the Calendar of Major Weather Types of Europe (*Kalender der Grosswetterlagen Europas*), for the timespan 1881–1939. These types, or patterns, have been defined as “the mean distribution of air pressure above a large region, at least as large as Europe, which remains unchanged over the course of several days”.

Once the characteristics of certain types of weather have been established, together with the geographical location of control centres and the extent of frontal zones, one can divide the types of air circulation in layers where there is either a “central maximum”, or a “central minimum”, or “linear flow”.

Moreover, taking into account the geographical location of control centres (observation sites) and the frontal zones, one can subdivide the weather in cyclonic and anticyclonic behaviour patterns.

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All these assertions have led to defining 21 types of weather over the European and East-Atlantic region. After the methods of synoptic analyses have been improved, after the second world war, improvements have been also carried out in regard to this division of weather types. In 1950 and 1951, the Calendar of the *Grosswetterlagen* has been further improved, and in 1952 Hess and Brezowsky have created the "Catalogue of weather situations in Europe". This Catalogue covered the general situations of weather, beginning with 1st of January, 1881, until the 31st of December, 1950. The method used by these authors was to analyse the circulation (flow) of air in the central region of Europe, by the dominant direction of air flow at ground level:

– Western (zonal) circulation
– meridional circulation
– combined circulation.

These Hess-Brezowski types of weather have been defined either by the direction of air flow, or by the position of centres of baric action, all of which generate different weather. With few exceptions, any real situation can be assimilated to one of these typical situations. Following this scheme, for the timespan of one year, 29 structures or types of circulation have been defined. These structures describe the field of mean air pressure at ground level, and the topography of 500 hPa level. Thus, at synoptic scale for Europe, there have been define four types of western (zonal) circulation, eighteen types of meridional circulation and eight types of blocking.

The 29 structures are:

A. *Grosswetterlagen* of zonal circulation:
1. Western, anticyclonic (WA)
2. Western, cyclonic (WZ)
3. Western, southern (WS)
4. Western, progressive (WW)

B. *Grosswetterlagen* of combined circulation:
5. South-western, anticyclonic (SWA)
6. South-western, cyclonic (SWZ)
7. North-western, anticyclonic (NWA)
8. North-western, cyclonic (NWZ)
9. Pressure maximum over central Europe (HM)
10. Anticyclonic bridge over central Europe (BM)
11. Low pressure area over central Europe (TM)

C. *Grosswetterlagen* of meridional circulation
12. Northern, anticyclonic (NA)
13. Northern, cyclonic (NZ)
14. Pressure maximum over the North Sea, anticyclonic (HNA)
15. Pressure maximum over the North Sea, cyclonic (HNZ)
16. Pressure maximum over the British Archipelago, anticyclonic (HB)

17. Low pressure trough over central Europe (TRM)
18. North-eastern, anticyclonic (NEA)
19. North-eastern, cyclonic (NEZ)
20. Pressure maximum over the Fino-Scandinavian area, anticyclonic (HFA)
21. Pressure maximum over the Fino-Scandinavian area, cyclonic (HFZ)
22. Pressure maximum over the North Sea and Fino-Scandinavian area, anticyclonic (HNFA)
23. Pressure maximum over the North Sea and Fino-Scandinavian area, cyclonic (HNFZ)
24. South-eastern, anticyclonic (SEA)
25. South-eastern, cyclonic (SEZ)
26. Southern, anticyclonic (SA)
27. Southern, cyclonic (SZ)
28. Low pressure field, centered above the British Archipelago (TB)
29. Low pressure trough over the Western Europe (TRW).

Until now (2010), the Catalogue has been edited several times. For the scope of this study, we have used the edition that covers the period 1st of January, 1881 – 31st of December, 1998 [4, 5].

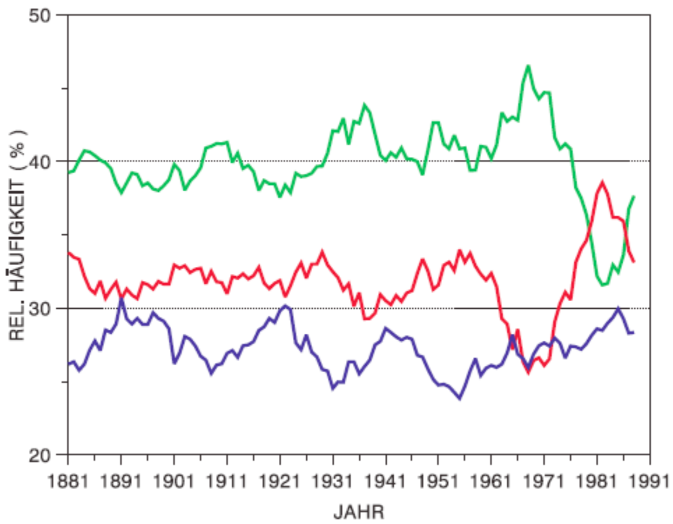


Fig. 1 – Relative frequency of the types of atmospheric circulation for Europe between 1881 and 1991 [2] – blue: zonal; red: combined; green: meridional.

The goal of this study is to make a simple statistics on the weather situations in which Romania has been experiencing floods and major flash floods, during 1948 and 1995. A simple correlation between the Grosswetterlage and the atmospheric circulation over Romania during these events will be presented, along with several other statistics related to their occurrence.

Section 2 of this paper presents the information gathered about 29 events of floods and flash floods in Romania, and the methods used to analyse and compartmentalise it.

Section 3 presents the primary results of the analysis, as distribution and frequency of events linked to certain circulation patterns, seasonal distribution, and other observations.

In Section 4 the conclusions to this study are being presented, along with a subjective model of identifying potentially hazardous situations of floods and flash floods for Romania, as derived from the analysis performed over this set of events.

2. DATA AND METHODS

The *flood* is an overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding: it may last days or weeks. (NOAA/NWS, 2010)

The *flash flood* is a flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris or ice jam. (NOAA/NWS, 2010)

One can list, as causes of floods and flash floods, the following:

– abundant precipitation upstream of the affected areas. Precipitation episodes can be either convective (showers), or caused by the passing of fronts;

– warming in the high areas during wintertime, followed by melting of the snow layer and possibly rain;

– high concentrations of water in the upper (top) layers of soil, which leads to poor absorption capacity for the water from subsequent precipitation;

– extensive damage to dams and levies;

– debris that block the riverbeds.

For each of the time interval when there has been recorded and documented a flood, or major flash flood in Romania, we have studied the corresponding mean sea level pressure, the mean height of 500 hPa level and the mean pressure at the tropopause.

The graphs have been created using the reanalysis data of NOAA/NCEP/ NCAR, with the web-page interface on their site. The mean field over each time interval has been obtained from the daily means of the field over the same interval.

– mean sea level pressure: “Sea level pressure – Daily”. URI address:
http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.surface.html

– geopotential height of 500 hPa: “Geopotential Height – Daily”. URI address:
http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.pressure.html

– pressure at tropopause: “Pressure – Tropopause – Daily”. URI address:
http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.tropopause.html

The analysis that we present here did not take into account the type of precipitation (frontal, convective, short-time showers or persistent rain), nor the thickness of snow cover that has been melting during the warming episodes and contributed to the increase of the water volume transported downstream, nor the water content of the upper layer of soil (10^1 cm). The analysis has been performed over the entire set of cases, and as such it does not differentiate between the direct causes of floods and flash floods, their secondary causes (the melting of snow layer) and the geographical elements intrinsic to the observations (geographical disposition of hydrometric stations, of river beds and affected settlements).

It is acknowledged that air mass advection of tropical origin over Romania lead to periods of extremely high temperature. Some very hot such periods were generally followed by short events of atmospheric instability, sometimes for the entire country [2]. Of similar importance are severe weather intervals caused by frontal behavior, either cold fronts from above Western and Central Europe, occluded fronts near the Carpathian Mountains, and warm fronts coming from the South of Romania.

However, in regard to the scope of this project – that is, to make a statistics of the air circulation types prevalent during the floods and flash flood events in Romania, these elements that we have hereby ignored may, and will be used in further analyses of all the events, which will take into account the small-scale or local effects, and the conditions prior to the onset of abundant precipitation.

The area over which the analysis has been performed is bounded by the geographical coordinates of (30–70) degrees Northern latitude, and (0–50) degrees Eastern longitude.

We have preferred this area because Romania is close to its center, and this area is being influenced by several semi-permanent pressure systems and their extensions (ridges and troughs) and also by transitory pressure systems. These systems are:

– the Azoric Anticyclone
– the Scandinavian Anticyclone
– the East-European Anticyclone
– the low pressure system off Iceland
– Mediterranean cyclones.

A typical series of the graphical analysis performed for each of the 29 cases of floods and flash floods is presented in Fig. 2.

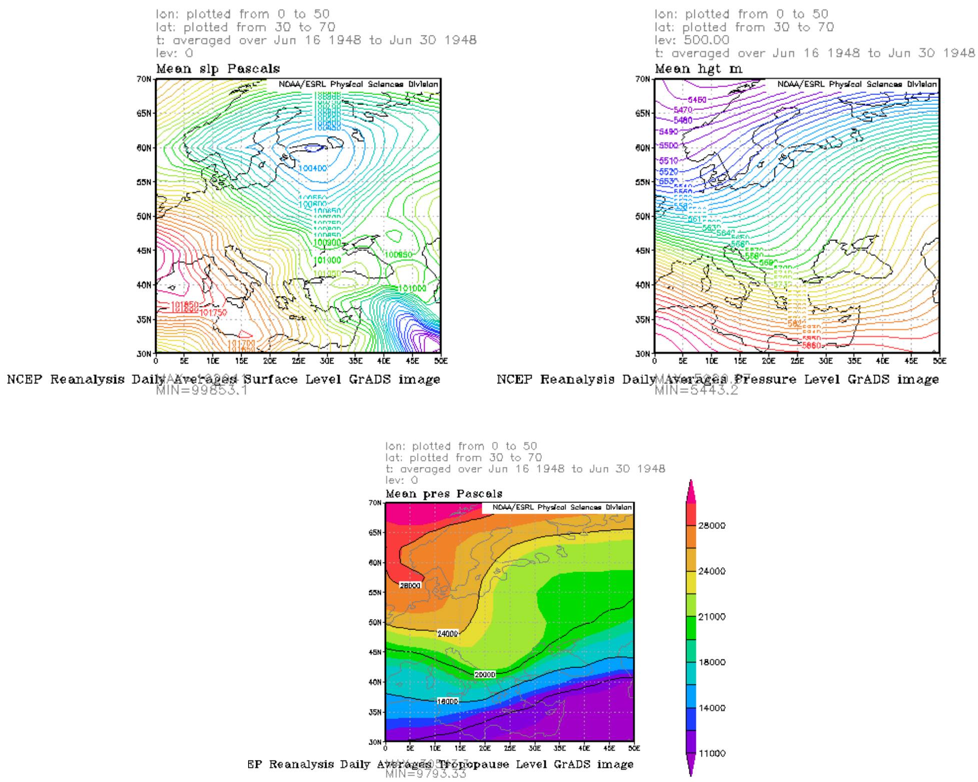


Fig. 2 – Mean sea level pressure; mean geopotential height; mean pressure at tropopause, for the floods and flash floods event during 16–30 June 1948 in Romania.

We have analyzed these fields for each of the 29 events of floods and flash floods in Romania. The 29 events, documented in 18 years, have been selected due to the quality and quantity of information related to each of them, and also due to the temporal limit of the reanalysis dataset of NCEP/NCAR, which starts at 1948.

The years with floods and flash floods that we have taken into account in our analysis are: 1948, 1955, 1956, 1960, 1966, 1969, 1970, 1975, 1978, 1979, 1980, 1985, 1988, 1989, 1991, 1993, 1994 and 1995.

We have separated the affected areas in Romania by their positioning relative to the Carpathian arc, thus:

– intra-Carpathic areas (CARIN): Maramures, Crisana, Banat, Transilvania
– extra-Carpathic areas – East (CAREX-E): Moldova
– extra-Carpathic areas – South (CAREX-S): Oltenia, Muntenia, Dobrogea.

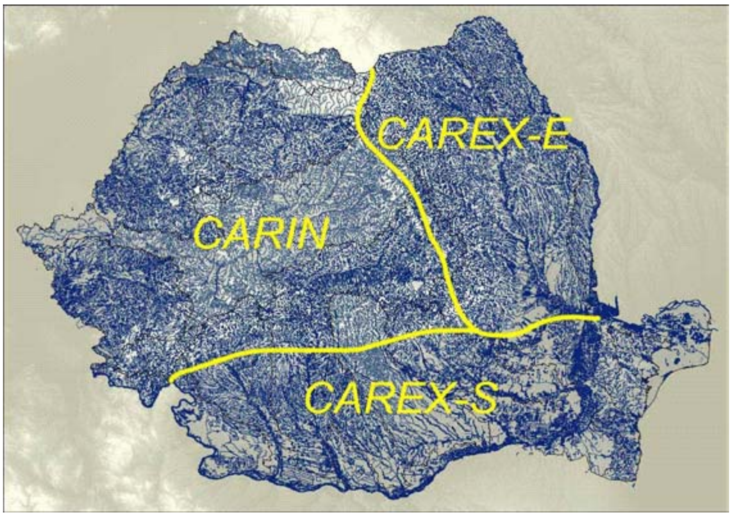


Fig. 3 – Hydrological map of Romania, with generic subdivision into intra-Carpathic (CARIN), and extra-Carpathic areas (CAREX-E, CAREX-S).

We have preferred this approach because:

– the intra-Carpathic areas are the first, and generally the most affected areas by low pressure systems generated North of Romania;

– the extra-Carpathic areas are the first, and generally the most affected areas by low pressure systems generated South of Romania;

– the extra-Carpathic areas, and Romanian Plain especially, are predisposed to convective storms more than the rest of the territory;

– on the inside of the Carpathian arc, the terrain is higher than in the lowlands and plains area outside of it and is predisposed to lower temperatures than the rest of the territory (mountain areas excluded).

Romania has been subject to floods and flash floods for a long time, as the documented history show. A detailed work [1] presents the statistics of flash floods documented on the interior rivers in Romania, since the 16th century.

Table 1

Frequency of flash floods, by season, between the 16th and 20th century [1]

Century	***Years with floods***	***Number of flash floods***	***Flash floods, from total of events***			
			Spring	***Summer***	***Autumn***	***Winter***
XVI	10	8	-	6	1	1
XVII	19	20	3	12	3	2
XVIII	26	25	6	12	3	4
XIX	15	18	6	10	2	-
XX	40	46	14	22	4	6
total	110	117 (100%)	29 (25%)	62 (53%)	13 (11%)	13 (11%)

In the following table we have condensed the information about circulation of air over central Europe [4, 5] and Romania, in each of the cases of floods and flash floods during 1948 and 1995. The summary of these events has been taken from [1].

Table 2

Grosswetterlage in central Europe ([1]) and atmospheric circulation in Romania associated with each flood and flash flood event, between 1948 and 1995

Case index	***Year***	***Month (in year)***	***Days of the month***	***Type of Hess-Brezowski circulation, in days and abbreviation***	***General atmospheric circulation over Romania, 24 hours before the reference interval***	***General atmospheric circulation over Romania during the reference interval / Value (hPa) and orientation of the mean isobar***		***Areas affected***
1	1948	6	after 16.06	7WZ, 3NEA, 3WA, 2TM	NE	NE; SW	1013, SW	CARIN, CAREX-E
2		6	21 – 27	2WZ, 3NEA, 1 WA	SW	SW; N; low pressure system	1008, NW	CAREX-S
3	1955	3	8 – 20	2HNFZ, 6BM, 5NZ	S	SE; E; NE	1012, SE	CAREX-S
4		10	9 – 10	BM	SW	E; SE	1021, SE	CARIN
5	1956	4	26	TRW	E; E-NE; low pressure system	S	1010, S	CARIN
6	1960	6	16 – 17	HM	NE	NE	1019, NE	CARIN, CAREX-S
7		9	22 – 24	1WW, 2BM	S	SE; E	1020, SE	CAREX-S
8	1966	5	29 – 31	3HB	S; SE; low pressure system	NW; W; low pressure system	1006, NW	CARIN

Table 2 (continued)

9	1969	6	6 – 13	2NEZ, 5NEA, 1U	SW+NE, low pressure systems	SE; E; N; NW; low pressure system	1007, NE	CAREX-E
10		7	30	HFZ	E	SE	1020, SE	CARIN
11	1970	5	~ 1 – 20	1TRM, 3NEZ, 6HFA, 4TM, 1U, 3NEA, 1U, 1NWZ	NE	N; NW; NE; low pressure area; anticyclonic ridge from the N; S; low pressure area	1012, N	CARIN, CAREX-E, CAREX-S
12	1975	7	~ 1 – 30	6NEZ, 1U, 4TB, 5SWA, 9WZ, 5BM	S	W; low pressure system; N; Icelandic trough; S; anticyclonic ridge; SW; NW	1013, NE	CARIN, CAREX-E, CAREX-S
13	1978	5	2 – 3	WS	S	S; low pressure system	998, SW	CARIN
14	1979	6	~ 15 – 30	4HB, 11BM	SW	S; NE; E; low pressure system	1014, E	CAREX-E, CAREX-S
15	1980	7	29	HNFA	NE	E	1013, E	CARIN
16	1985	6	11	TRM	Azoric ridge	Icelandic trough to the North of Greece	1013, NW	CAREX-S
17	1988	6	1 – 11	3WZ, 4TRW, 4HNZ	low pressure area	Icelandic trough; low pressure system	1009, N	CAREX-E

Table 2 (continued)

18	1989	5	7 – 9	BM	SE	low pressure system	1005, N	CARIN
19	1991	6	3	WZ	SE	SW, S	1014, S	CAREX-E
20		6	10	WZ	N; low pressure system	N	1014, N	CAREX-E
21		6	29	TRM	NW	NE	1012, NE	CAREX-E
22		7	3	HNFA	NE	NE	1012, NE	CAREX-E
23	1993	1	~ 10 – 20	5WZ, 3WA, 3WZ	N; Azoric ridge	W; anticyclonic; Icelandic trough; anticyclonic	1027, NW	CARIN, CAREX-E
24		12	~ 10 – 20	WZ	E	anticyclonic bridge; Icelandic troughs	1015, W	CARIN, CAREX-E
25		12	21	WZ	W	W	1005, W	CARIN
26	1994	8	26	TB	S; low pressure system	low pressure system	1003, SE	CAREX-E
27	1995	5	23 – 25	2HM, 1TRW	SE	NW	1012, NW	CARIN, CAREX-S
28		6	28 – 29	1HB, 1NWA	N	N	1005, N	CAREX-E
29		12	~ 23 – 31	4WS, 4HNA, 1 SEA	SW	SW; Icelandic troughs	1009, SW	CARIN, CAREX-S

3. RESULTS

One can summarize the characteristics of circulation above Central Europe and Romania, over the set of 29 events of floods and flash floods.

3.1. As to the Hess-Brezowski types of circulation, the distribution of the analysed events is as follows:

Month	*Hess-Brezowski circulation type this month, during the analysed events (number of days and abbreviation)*	*Hess-Brezowski circulation type this month, on the total of events (abbreviation and number of days)*
1	(5WZ, 3WA, 3WZ)	WZ: 8
3	(2HNFZ, 6BM, 5NZ)	BM: 6
4	(1TRW)	TRW: 1
5	(3HB), (1TRM, 3NEZ, 6HPA, 4TM, 1U, 3NEA, 1U, 1NWZ), (1WS), (3BM), (2HM, 1TRW)	HPA: 6 TM: 4 HB, NEZ, NEA, BM: 3
6	(7WZ, 3NEA, 3WA, 2TM), (1HM), (2NEZ, 5NEA, 1U), (4HB, 11BM), (1TRM), (3WZ, 4TRW, 4HNZ), (1WZ), (1WZ), (1TRM), (1HB, 1NWA)	WZ: 12 BM: 11 NEA: 8
7	(1HFZ), (6NEZ, 1U, 4TB, 5SWA, 9WZ, 5BM), (1HNFA), (1HNFA)	WZ: 9 NEZ: 6 SWA, BM: 5
8	(1TB)	TB: 1
9	(1WW, 2BM)	BM: 2
10	1BM	BM: 1
12	(1WZ), (1WZ), (4WS, 4HNA, 1SEA)	WS, HNA: 4

We see a prevalence of WZ pattern of circulation during the winter (January) and summer (June), and of BM pattern during the same time of the year.

3.2. As to the Hess-Brezowski types of circulation, their frequency by the season in which the events were recorded is as follows:

Season (as series of three months each)	*Prevalent circulation type (abbreviation)*	*Prevalent circulation type (number of days)*	*Fraction of a generic season (3 months of 30 days each) (%)*
Spring (3 – 5)	BM	9	10
Summer (6 – 8)	WZ	21	23
Autumn (9 – 11)	BM	3	3
Winter (12 – 2)	WZ	8	8

On the set of events we have analysed, the most frequent pattern of circulation was WZ, during the summer.

3.3. As to air circulation, as seen in the field of sea level pressure, as mean values on each reference interval, over Romania and its immediate vicinity (<500 km):

Orientation of air circulation, or dominant pressure system, at sea level	***Case index***	***Fraction of total (%)***
Low pressure system	8, 9, 11, 13, 17, 18, 22, 26, 27, 29	34.5
North-Eastern	10, 12, 15, 21, 28	17.2
North-Western	1, 2, 16, 23, 25	17.2
Northern	6, 20	6.9
Eastern	7, 14	6.9
South-Eastern	3, 4	6.9
Southern	5, 19	6.9
Western	24	3.4

Most of the events have taken place while near Romania there was a low pressure system.

3.4. As to air circulation, as seen in the height of 500 hPa level, as mean values on each reference interval, over Romania and its immediate vicinity (<500 km):

Orientation of air circulation at 500 hPa level	***Case index***	***Fraction of total (%)***
South-Western	1, 3, 5, 6, 11, 13, 16, 19, 26	31
Western	17, 20, 24, 25, 29	17.2
Low pressure system	8, 9, 18, 27, 28	17.2
Southern	2, 4, 14, 21	13.8
South-Eastern	7, 22	6.9
North-Western	12, 23	6.9
Convergence	15	3.4
Eastern	10	3.4

Most of the events have taken place while above Romania, the circulation at 500 hPa level was from the South-West.

3.5. As to the level of tropopause, the position of the nearby isobar, closest to the Southern border of Romania (to the South) during each event is as follows:

Mean isobar (hPa) South of the Southern border of Romania (<100 km)	***Case index***	***Fraction of total (%)***
190	4	3.4
200	1, 2, 7, 15, 26	17.2
210	12, 14, 22, 29	13.8
220	5, 6, 19, 20, 21, 24, 25, 28	27.5
225	9, 10	6.9
230	16, 17, 27	10.3
240	8, 13, 23	10.3
250	3, 11, 18	10.3

3.6. As to the time of year (season), the distribution of the events of floods and flash floods in the analysed set is as follows:

Season (as series of three months each)	*Case index*	*Fraction of total (%)*
Summer (6 – 8)	1, 2, 6, 9, 10, 12, 14, 15, 16, 17, 19, 20, 21, 22, 26, 28	55.1
Spring (3 – 5)	3, 5, 8, 11, 13, 18, 27	24.1
Winter (12 – 2)	23, 24, 25, 29	13.8
Autumn (9 – 11)	4, 7	6.9

Most of the floods and flash floods have taken place in June.

During March, April, August, September and October there has been only one event each month.

During February and November there has not been any recorded event in this set.

3.7. As to the areas affected by floods and flash floods, the statistics is as follows:

Affected area, as positioned in regard to the Carpathian arc	*Case index*	*Fraction of total (%)*
CARIN	1, 4, 5, 6, 8, 10, 13, 15, 18, 23, 24, 25, 27, 29	48.2
CAREX-E	1, 9, 14, 17, 19, 20, 21, 22, 23, 24, 26, 28	41.3
CAREX-S	2, 3, 6, 7, 14, 16, 27, 29	27.6
CARIN, CAREX-E, CAREX-S	11, 12	6.9

4. CONCLUSIONS

First of all, we must mention that the results we have obtained refer strictly to the set of 29 events of floods and major flash floods in Romania, such as they have been documented and presented in [1].

4.1. As to the synoptic context for Europe, in the Hess-Brezowski typology:

The type of circulation that is most associated with events in our set is **WZ** (***Westlage, zyklonal***), that is a prevalent zonal, cyclonic circulation at ground/sea level over central Europe.

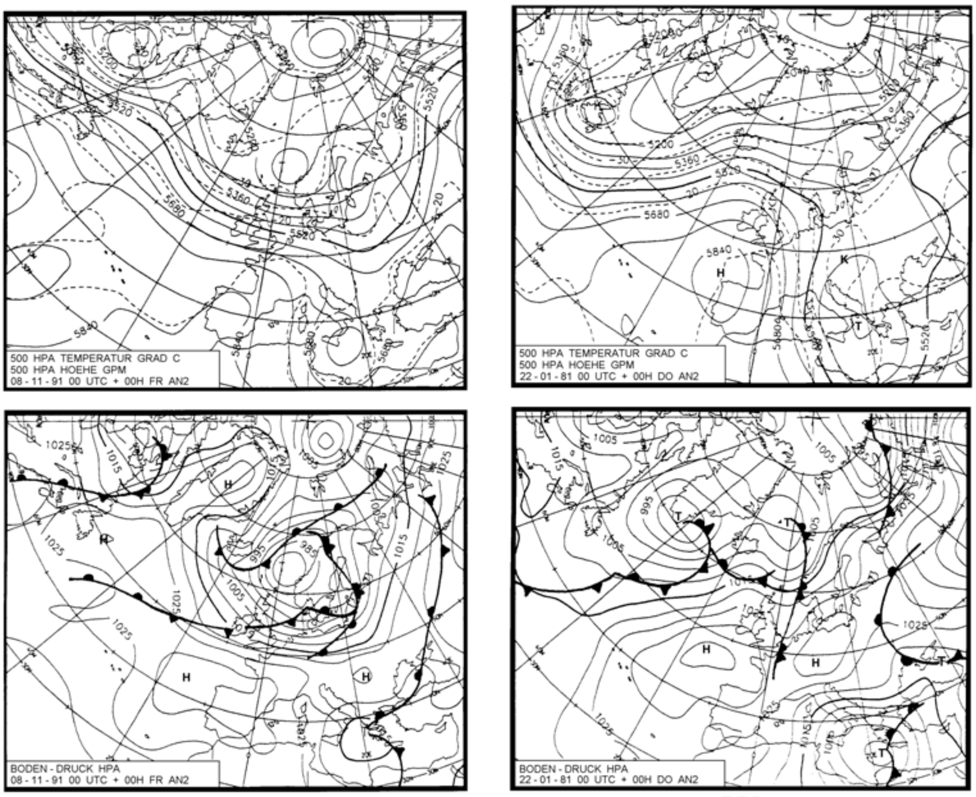
This type of circulation favours the advection of warm and humid air from the Mediterranean Sea over Romania.

The number of days during which this circulation was prevalent, regardless the time of the year, is 29.

The second most frequent type of circulation associated with events in our set is BM (*Hochdruckbruecke/Ruecken Mitteleuropa*), that is an anticyclonic bridge over the central Europe.

In this situation, Romania is at the South of the bridge, in an area of low air pressure where the air circulation is cyclonic and where the influence of either Mediterranean Sea, or the Black Sea, is poignant.

The number of days during which this circulation was prevalent, regardless the time of the year, is 28.



WZ BM

Fig. 4 – The *WZ* and *BM* Hess-Brezowski types of circulation over central Europe [4, 5].

4.2. As to the synoptic context for Romania, regarding air circulation at sea level:

34.5% of the events (the majority of them) have been taking place while over Romania, or in its immediate vicinity, there have been low pressure systems (cyclones).

4.3. As to the synoptic context for Romania, regarding air circulation at 500 hPa level:

31% of the events (the majority of them) have been taking place while the flow was from the South-West.

4.4. As to the level of tropopause in the geographical region of Romania:

27.5% of the events (the majority of them) have been taking place while the isohypse of 220 hPa was very close (< 100 km) South of Romania.

4.5. As to the affected areas:

– the most frequently affected areas were the CARIN: 48.2%

– the least frequently affected areas were the CAREX-S: Oltenia, Muntenia and Dobrogea: 27.6%

– most of the hydrographic basins in Romania (CARIN, CAREX-E, CAREX-S) were affected in only 2 cases out of 29 analysed: 6.9% of total.

4.6. Most of the floods and flash floods were being recorded in June, with 11 cases out of 29 analysed: 38%.

Due to the geographical location of Romania, and its unique positioning relative to major (semi-permanent) and transitory pressure systems, it is of great importance to have in mind the synoptic conditions during which more attention must be generally granted, directly related to the probability of occurrence of floods and flash floods.

The results of this study help in establishing some simple patterns for the occurrence of these events in Romania, and eventually a subjective model of assessing the probability for such events to occur exclusively linked to air circulation over Europe and Romania.

The basic tenets of this subjective model are the following:

1. Most of the events have taken place either when there has been a low pressure system in the immediate vicinity of the country, or when the pressure field was generally weak. Also, the blocking situations are of great interest because they lead to the persistence of advection of warm and humid air from the Mediterrannean Sea.

2. Southern and South-Western circulation lead to both warming and precipitation. One must separate here the situations when warm and humid air is being transported from above the Mediterranean Sea, from those when warm air, with low water vapour content, is being transported to Europe due to the North-African Anticyclone.

3. Eastern circulation brings humid air from above the Black Sea, so one can expect heavy precipitation in the East and centre of the country. Situations of Eastern blocking (caused by the – mostly cold – East-European Anticyclone) are worthy of mentioning, when cyclones from South of Romania can advance well near the country. As such, heavy precipitation can occur either on warm (Mediterranean cyclones, from the South), or cold (anticyclonic, from the East) background.

4. Icelandic low pressure troughs can lower to the North of the Mediterranean Sea, and therefore onset warm and rainy weather during cold months (December, January). As such, cyclones generated in the Mediterranean will gradually "fill up" with arctic (and polar) air, and tend to reactivate, thus leading to persistent bad weather in the Southern and South-Eastern Europe.

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