ATMOSPHERIC PRECIPITATIONS GREATER THAN 10 MM IN THE CENTRAL PART OF THE ROMANIAN PLAIN AND THEIR SYNOPTIC CAUSES

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ABSTRACT

Atmospheric precipitation is one of the most important features of the climate. The research of the territorial distribution of the precipitation amount has a considerable practical, applicative and theoretical interest. Thus, the study of all the extreme and complex conditions of formation and falling of precipitation in the central area of the Romanian plain is necessary for the use of water according to the distribution of the precipitation regime as well for the prevention and combating on their negative effects. These may have various causes: frontal rainfall in the case of Atlantic cyclones and Mediterranean cyclones on various tracks, and convective cells forming within the air masses or under the action of radiation cooling processes or by the development of thermal convection (clouds with vertical development).

In this paper, we have analyzed the synoptic conditions that generate precipitation in the central part of the Romanian Plain. Thus, with the help of the ROCADA database, all the days between 1981-2013 time period that gathered more than 10 mm amount of precipitation were extracted. The data were chosen for an area delimited by 44°42’ and 43°37’ N, and 23°56’ and 26°35’ E coordinates, assigned to our study area. The days were analyzed from a synoptic point of view using the maps available in the Global Forecast System reanalysis, on the www.wetter3.de website. This brought about seven synoptic causes that generate precipitation, represented by the Atlantic cyclones, Mediterranean cyclones with a type I, II and IV track according to the Bordei-Ion classification [1], high altitude cut-off low cyclones and by the high atmospheric instability periods represented by the long-wave troughs and also by the warm air advection in a high pressure atmospheric condition.

Keywords: ROCADA database, Romanian Plain, synoptic conditions, atmospheric precipitations

INTRODUCTION

The Icelandic low is considered to be the second major centre of atmospheric action for the European continent, with a multianual variability in terms of intensity and position which is determined by complex interactions in the Atlantic sector [2]. In Romania the ***cyclones with Atlantic origin*** (Figure 2) act, especially during cold season (October-December, March) but they occur also according to some authors in July and August [3]. Due to the fact that they are blocked/stopped by the Carpathians, the winter season is characterized by a small amount of rainfall to the East of the Carpathians, which are known to impose major differenciations on the climate of Romania [4], especially and by more significant quantities in the western and north-western regions [5].

Besides this an important role in the changes of the weather aspect in our country is the evolution of ***Mediterranean cyclones*** [6, 7]. They are generated in the central and western parts of the Mediterranean basin, in the contact area between the wet and cool air moving from the Atlantic Ocean and the warmer air that stays above these regions. They are born in the cold semester of the year (October-March) with a higher frequency in January and February and are moving on different trajectories to the east or northeast [8-11]. The Mediterranean depressions across the Balkan Peninsula bring important changes in the weather, especially in the Romanian Plain. When the trajectories of the Mediterranean cyclones affect the Pannonian Depression, their influence is felt especially in the western half of it [4].

Cut-off low altitude cyclones represent cyclonic regions in the low troposphere resulting from the jet stream mounds on their southern side and they are characterized as small cold air masses detached from the polar vortex that have descended to lower latitudes [12]. These cyclones develop in the Mediterranean basin, they can either be stationary or move eastwards [7] and they are characterized by the formation of clouds with strong vertical development and by the production of significant amounts of precipitation that lead to temperature differences between the ground level and higher altitudes in the atmosphere [13, 14]. Here, the aspect of the weather is influenced by the terrestrial surface above where these cyclones move. For example, the most exposed places are the heavily heated ground areas, while aquatic surfaces inhibit the development of convective formations [15]. These cyclones have higher frequency in the warm semester of the year, with peak activity recorded at the end of the spring and the first two months of the summer season [16, 17].

When cold air masses associated to ***long-wave troughs*** from Northern Europe meet in the geographical region of our country, hot and humid air masses cause a very high vertical air instability that leads to significant precipitation in Romania [16], including the Romanian plain [1]. The main reason for this is the exposure of the slopes in the extra-Carpathian regions, favoring the orographic convection, but also the role of the mountain chain acting as an orographic barrier that enhances the accumulation of large amounts of water in a relatively short time [18].

On the territory of Romania, the highest number of torrential and convective rainfall occurs especially in the beginning of the summer, in June and July, in the hilly and plain regions behind the Carpathians, being determined by advective and local processes, but also in August, though less numerous than in the other two months, due to the fact that drought periods predominate in the regions in front of the Carpathians, determined in particular by local convective processes [19].

Advection of warm air masses in a high pressure atmospheric condition produces approximately the same phenomena as cold air advections, but noticing that they are not always as violent, and in the cold semester of the year, most often, they produce precipitation in the form of rain, snow or drizzle, fog and air heating, which can cause slowly melt of the snow layer.

DATA AND METHODS

This paper is based on the synoptic analysis of the days when the precipitation amount was greater than 10 mm between 1981 and 2013, which were based on the sea level pressure synoptic maps from Deutsche Wetterdienst and 500 hPa geopotential height from Climate Forecast Systems of NOAA, available at www.wetter3.de, the GFS forecasting numerical model (Global Forecast System). The days were extracted from the ROCADA data base [20] from the 44°42' and 43°37' N and 23°56' and 26°35' E (Figure 1) using the Windows PowerShell software through climate data operators (CDO – https://code.zmaw.de/projects/cdo/embedded/cdo.pdf). The data operators used to extract the specific data were the following: ***selyear*** to extract each year from 1981 to 2013, ***mergetime*** to merge all the years into a single file and ***eca_r10mm,*** to select only the days with an amount of precipitation greater than 10 mm from the file that was resulted after using ***mergetime***.

The two maps with synoptic causes of precipitation in the Romanian plain were made by using ERA-Interim data with mean sea level pressure produced at 12 UTC which involves observations between 03 UTC and 15 UTC. These data have a spatial resolution of 0.12x0.125° and were taken for the European continent between 73.5 ° N 27.0 ° W and 33.0 ° N 45.0 ° E [21].

ROCADA data and Era-Interim data are in the .nc format or, more precisely, NetCDF (Network Common Data Form), a spatial-time format for multidimensional variable data storage, in our case with climatic data (https://www.unidata.ucar.edu).

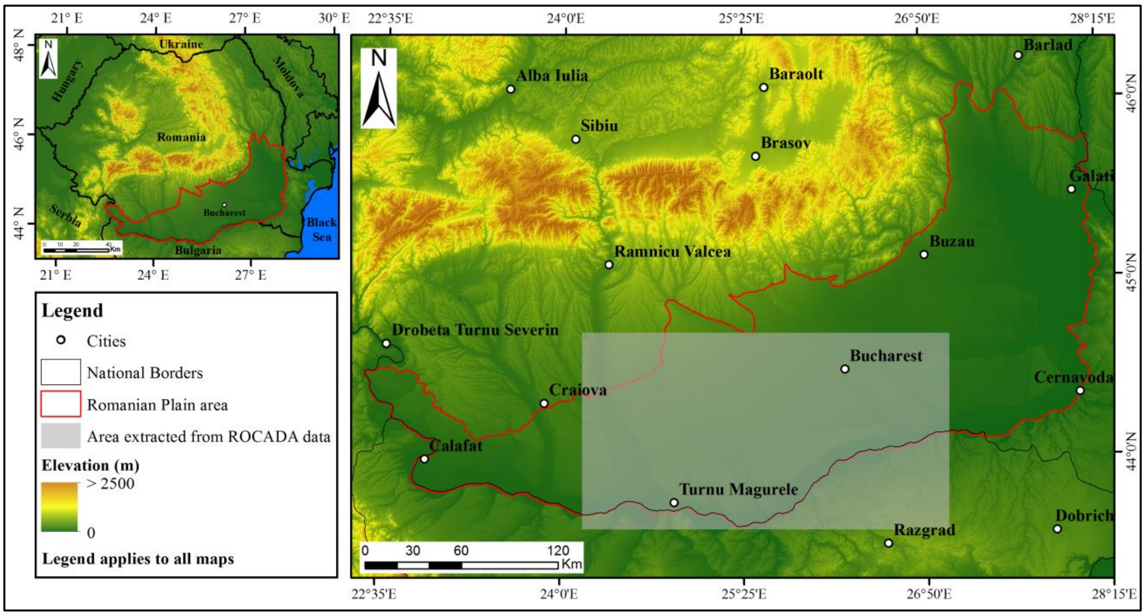

Figure 7. The geographic location of the Romanian Plain and the area from which ROCADA was extracted

RESULTS AND DISCUSSION

Mediterranean Cyclones may have transbalcanic trajectories, crossing Romania especially from south-west to north-east [22], leaving precipitations in the Romanian Plain, on the slopes of the Subcarpathians and the Southern Carpathians. In other words, the greater amount of precipitation between the Carpathians and the Danube space is mainly due to Mediterranean cyclones on southern or eastern components if the cyclones reactivate above the Black Sea [1].

The classic track I, that crosses perpendicularly the Dinars and Middle Carpathians and the crosses diagonally the Pannonic Depression is maximum in the warm period of April to September. It is believed that cyclones with this track leave precipitation only in the north-western, western and south-western parts of the country [6] (Figure 2). They often start from the Gulf of Genoa, migrate to the North Adriatic Sea, the Pannonian Plain, and then Poland, of which only 25% have a clear influence on the weather in Romania [23]. Mediterranean cyclones with track II generally move from the northwest of the Mediterranean Sea to the Balkan Peninsula and in our country affect Bărăgan Plain, Dobrogea and Moldova, and then pass to Ukraine. It shows maximum activity in the cold semester and more precisely at the end and beginning of it [24] and causes precipitation especially in eastern Romania [6, 23] (Figure 3).

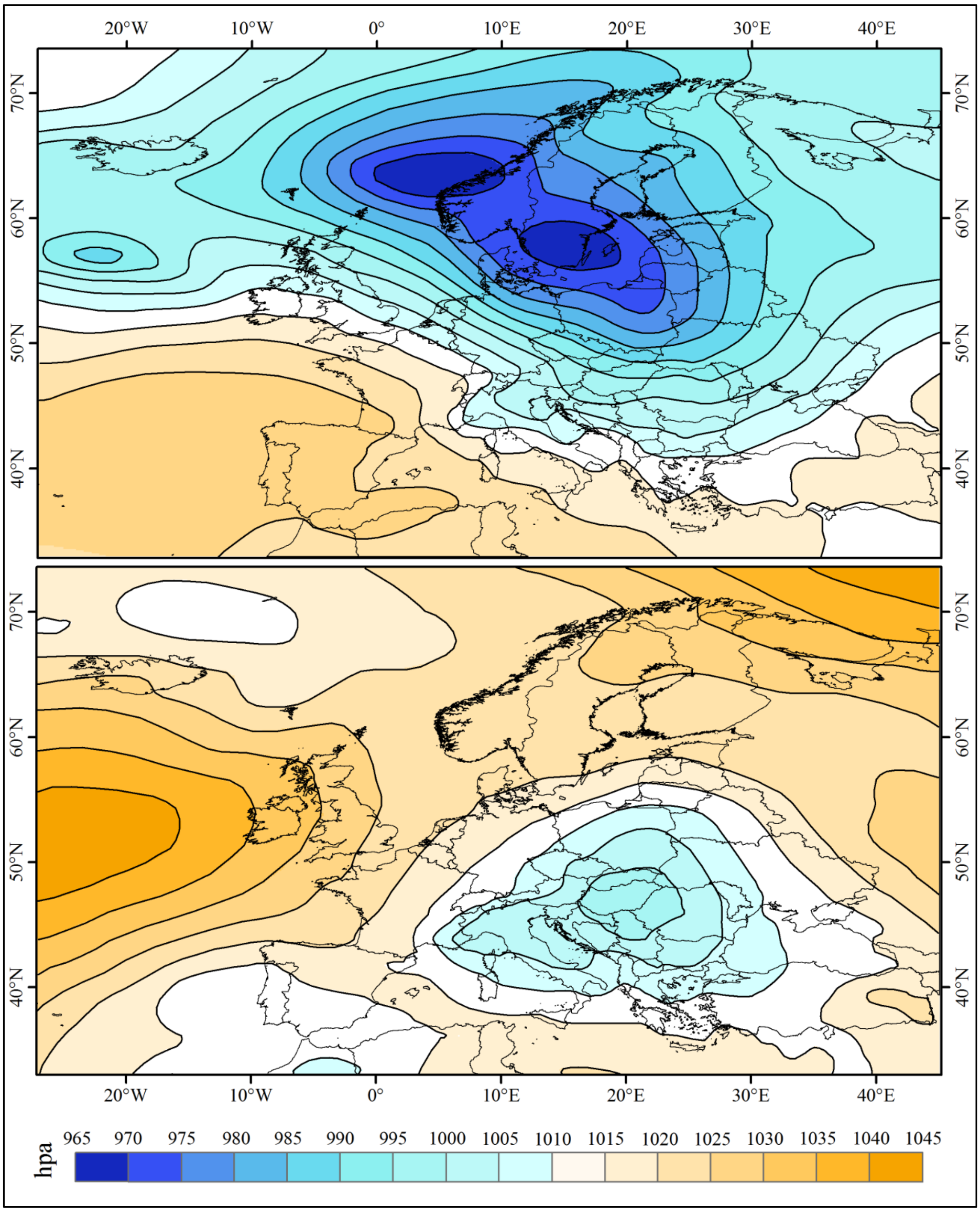

Figure 8. Cyclone of Atlantic origin on March 1, 2008 (top) and cyclone of Mediterranean origin with track I on March 25, 2004 (bottom)

Mediterranean Cyclones with track IV affect most of the country, but especially the southern slopes of the Meridionals, the Subcarpathians of Oltenia and Muntenia and even the Getic Plateau, but also a large part of the Romanian Plain (Figure 3). They have the highest frequency in the Mediterranean basin (41%), of which only 10-11 cyclones per year, on average, directly or tangentially influence the weather in our country [23].

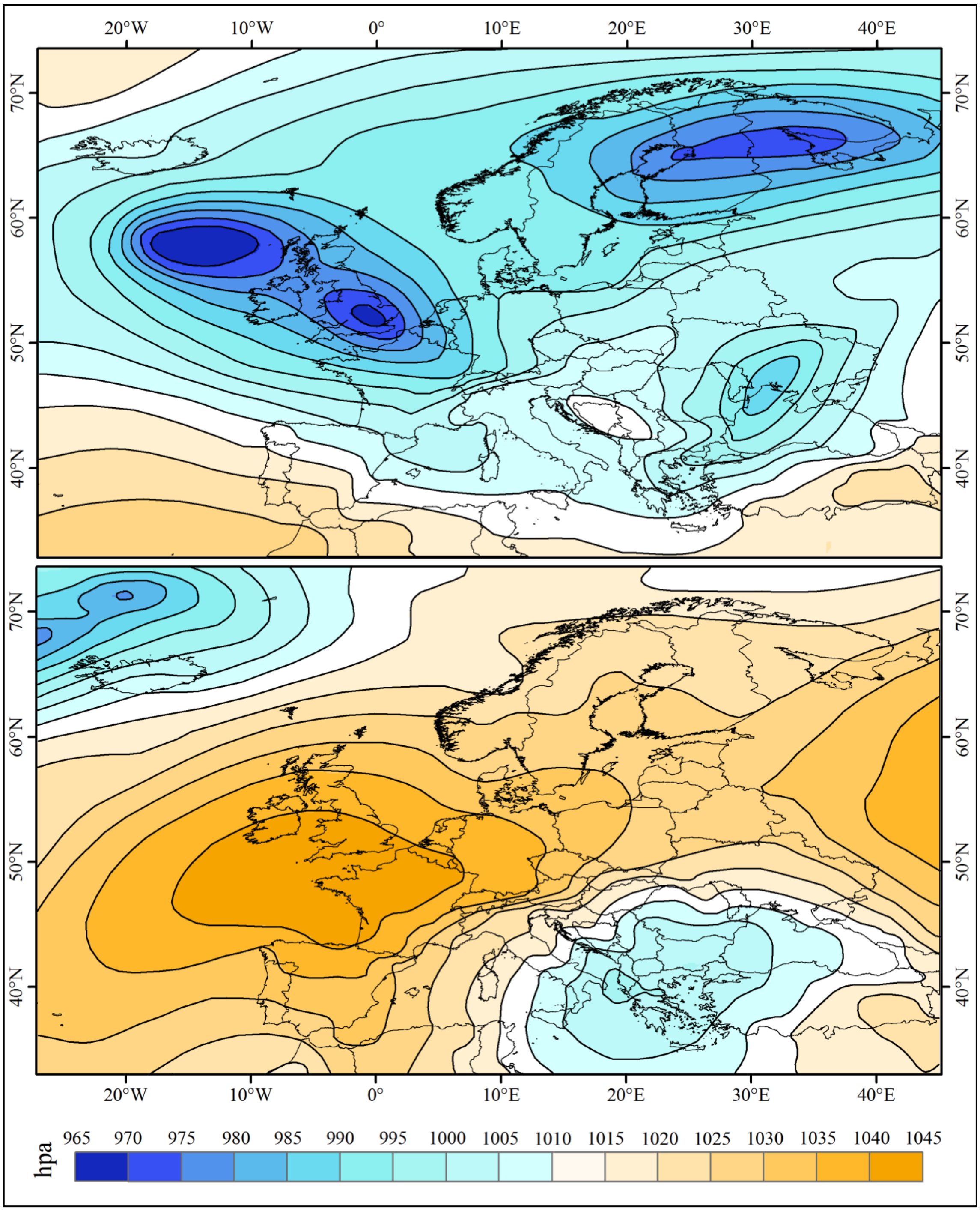

Figure 9. Cyclone of Mediterranean origin with track II on December 14, 1981 (top) and cyclone of Mediterranean origin with track IV on February 02, 1984 (bottom)

Under the influence of cyclones with retrogressive tracks it can be said that the evolution of the weather in our country in the cold half of the year is differentiated in the extra-Carpathian regions compared to the intracarpathian ones as in all classical atmospheric circulation of Mediterranean origin. They have an initial circulation on a normal southwest-northeast trajectory, and when they get above the Black Sea they get a retrograde circulation and come back over the territory of our country, generating large amount of precipitation especially in eastern Romania [24].

Of the total of 3552 days with amount of precipitation greater than 10 mm analyzed, cold air advections with a total of 1433 (40.3%) (Table 1) have the highest percentage, followed by the days with cyclonic activity. Thus, Mediterranean cyclones acted in 1008 days (28.2%) of which cyclones with a track I acted in 148 days (4.1%), Mediterranean cyclones with a track II acted in 653 days (18.4%) and those with a track IV acted in 207 days (5.7%). In terms of cyclones of Atlantic origin, they represent a total of 436 days (12.3%). Cyclones with retrogressive trajectory had 50 days (1.4%) and cut-off low cyclones had 469 days (13.4%). And last but not least, warm air advections in anticyclonical regime had 156 days (4.4%).

Table 3. Number of days and the synoptic causes of precipitations greater than 10 mm in the studied area during the period 1981-2013 and in the cold and warm semester

	Atlantic Cyclones	Mediterranean Cyclones			Retrogressive cyclones	Atmospheric instability		Warm air advections
		Med. I	Med. II	Med. IV		Troughs	Cut-off Low	
*	436 (12.3%)	148 (4.1%)	653 (18.4%)	207 (5.7%)	50 (1.4%)	1433 (40.3%)	469 (13.4%)	156 (4.4%)
**	228 (52.3%)	67 (45%)	348 (53.3%)	159 (76.8%)	19 (38%)	217 (15%)	26 (5.5%)	68 (43.6%)
***	208 (47.7%)	81 (55%)	305 (46.7%)	48 (23.2%)	31 (62%)	1216 (85%)	443 (94.5%)	88 (56.4%)

Number of days for: 1981-2013*; from which, in the cold semester**; and in the warm semester***

The average number of days per year of pluviogenetic causes obviously follows the same hierarchy as described above, so that cold air advections occur on average for 43 days a year, Mediterranean cyclones in 30 days a year, most days having Mediterranean cyclones with track II with an average of 20 days while Mediterranean cyclones with track IV are produced in 6 days and 4 for those with track I. Mediterranean cyclones with retrogressive tracks appear on the territory of our country for two days a year, while cyclones with Atlantic origin have 13 days. Regarding warm air advections in anticyclonical regime, they have an average number of 5 days a year. Cut-off low altitude cyclones occur on average of 14 days a year.

In the ***cold semester***, rainfall is generally low, because over the territory of the country predominates the anticyclonal regime, while clouds and convective precipitation do not develop very much [25]. In other words, the frequency of convective precipitation is reduced in favor of frontal precipitations, which leads to an increase in the number of days for almost all cyclone categories and a decrease for cold air advection or cut-off low altitude cyclones. Thus, the Mediterranean Cyclones had 574 cases, of which 67 days (45%) of the total of 148 for Mediterranean Cyclones with trajectory I, 348 days (53.3%)

of the total of 653 for cyclones with Mediterranean origin with track II and last but not least 159 days (76.8%) for trajectory IV cyclones (Table 1).

Cyclones of Atlantic origin have 228 (52.3%) days out of a total of 436 which means that they rank second in the hierarchy of pluviogenetic causes of precipitation in the Romanian Plain. Mediterranean cyclones with retrogressive circulation have 19 (38%) of the total of 50 days with a much lower activity than in the warm semester, as well as cold air advection with only 217 (15%) days of the total of 1433, and warm air advection in an anticyclonal regime with 68 (43.6%) of the total 156 days.

The variation during the ***warm semester*** of monthly precipitation quantities is directly related to the particularities of atmospheric circulation and, first of all, to the frequency, degree of development and direction of movement of the cyclones and, on the other hand, to the intensity of the thermal convection. Depending on the direction of the cyclone trajectories, the movement of the air masses and the fronts, the production of significant quantities takes place in some areas and less significant in others [25].

In the warm semester, convective precipitations predominates, especially in the second part of it (Table 1). Thus, most days with rainfall over 10 mm are due to cold air advections, with 1216 days (85%) out of a total of 1433 days, followed by the low-cut altitude cyclones with 443 days (94.5%) of the total of 469 days.

Table 4. Number of days and percentage of synoptic causes that generated atmospheric precipitations greater than 10 mm in the area studied between 1981 and 2013

	Atlantic Cyclones	Mediterranean Cyclones			Retro-gressive cyclones	Atmospheric instability		Warm air advections
		Med. I	Med. II	Med. IV		Troughs	Cut-off Low	
Jan	35 (8%)	5 (3.4%)	59 (9%)	21 (10.1%)	3 (6%)	30 (2.1%)	0	6 (3.8%)
Feb	29 (6.6%)	10 (6.8%)	53 (8.1%)	32 (15.5%)	4 (8%)	21 (1.5%)	0	18 (11.5%)
Mar	36 (8.3%)	8 (5.4%)	78 (12%)	24 (11.6%)	5 (10%)	29 (2%)	0	10 (6.4%)
Apr	51 (11.7%)	26 (17.6%)	73 (11.1%)	20 (9.7%)	17 (34%)	59 (4.1%)	21 (4.5%)	12 (7.7%)
May	58 (13.3%)	28 (18.9%)	68 (10.4%)	15 (7.2%)	12 (24%)	152 (10.6%)	77 (16.4%)	21 (13.5%)
Jun	43 (9.9%)	9 (6%)	54 (8.3%)	4 (1.9%)	2 (4%)	300 (21%)	96 (20.5%)	27 (17.3%)
Jul	19 (4.4%)	4 (2.7%)	13 (2%)	1 (0.5%)	0	322 (22.5%)	116 (24.7%)	8 (5.2%)
Aug	15 (3.4%)	5 (3.4%)	32 (5%)	1 (0.5%)	0	260 (18.1%)	91 (19.4%)	11 (7%)
Sep	22 (5%)	9 (6.1%)	65 (10%)	7 (3.4%)	0	113 (7.9%)	42 (9%)	9 (5.8%)
Oct	39 (9%)	9 (6.1%)	39 (6%)	8 (3.8%)	1 (2%)	70 (4.9%)	26 (5.5%)	14 (9%)
Nov	43 (9.9%)	20 (13.6%)	69 (10.5%)	19 (9.2%)	6 (12%)	31 (3.2%)	0	9 (5.8%)
Dec	46 (10.5%)	15 (10%)	50 (7.6%)	55 (26.6%)	0	46 (2.1%)	0	11 (7%)

Cyclonic activity is more intense in the first three months of the semester, so that the Mediterranean cyclones have a total of 434 days of which the Mediterranean cyclones with track I have 81 days (55%) out of a total of 148, the Mediterranean cyclones with track II have 305 days (46.7%) out of a total of 653, while Mediterranean with track IV have 48 (23.2%) of the total 207 days. Cyclones of Atlantic origin have a number of 208 days (47.7%) of 436 days, cyclones with retrogressive track have a number of 31 days (62%), while warm air advections in anticyclonal regime have 88 cases (56.4%) of 156 days.

Regarding the monthly activity of each synoptic cause (Table 2), it can be noticed that:

- Cyclones of Atlantic origin show a maximum in April, May and June by 51 (11.7%), 58 (13.3%) and 43 (9.9%) respectively and in October, November and December with 39 (9%), 43 (9.9) and 46 (10.5%) cases, respectively.
- Cyclones of Mediterranean origin with track I have peak activity at the beginning of the warm semester in April and May with 26 (17.6%) and 28 (19.9%) cases and in November and December with 20 (13.6%) and 15 (10%) respectively.
- Mediterranean cyclones with track II have the highest activity in March and April with 78 (12%), respectively 73 (11.1%) and 69 (10.5%) in November.
  Mediterranean cyclones with track IV have peak activity in February with 32 (15.5%) and December with 55 (26.6%) while cyclones with retrograde trajectories with much lower frequency have peak activity in April and May with 17 (34%) and 12 (24%) cases respectively.
- The frequency of the atmospheric instability generated by cold air advection starts to rise from May to September inclusive, the highest activity being in June with 300 (21%) cases and July with 322 (22.5%) cases while the high atmospheric instability generated by cut-off low cyclones shows the highest frequency in July with 116 (24.7%) cases. It is underlined that the cut-off low-activity cyclones are active only between April and October.
- Advection of warm air in the anticyclonal regime shows the highest activity in May with 21 (13,5%) cases, June with 27 (17,3%) cases and in February with 18 (11.5%) cases.

CONCLUSIONS

In the Romanian Plain and especially in its central area, according to the synoptic analysis made for all days with more than 10 mm between 1981 and 2013, it turned out that out of a total of 3552 days with amount of precipitation greater than 10 mm in the period 1981-2013, 28.2% were produced by cyclones of Mediterranean origin, 12.3% were produced by cyclones of Atlantic origin and 1.4% were produced by Mediterranean cyclones with retrograde trajectories. With regard to the causes that lead to vertical air instability, 13.4% were caused by cut-off low type cyclons, 40.3% were caused by eastward longwave through propagation, and 4.4% had were produced by warm air entrails in anticyclonal regime.

The Mediterranean Cyclones with Trajectory I act especially in the months of April, May, November and December, Mediterranean cyclones with trajectory II in March and November, while Mediterranean cyclones with trajectory IV, different from the others, have peak activity in December and February and minimum activity in April and May.

Although with lesser influence than that of Mediterranean cyclones, cyclones of Atlantic origin, the second barric center as important in Romania, is felt especially in the first three months of the two semesters of the year.

If the cyclone activity predominates in the cold semester, in the warm semester the convective precipitations produced by the cold air advection predominate in May, June and July and the precipitations produced by the low-cut cyclones only between April and October.

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