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Climatic features of the Romanian territory generated by the action of Mediterranean cyclones

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CLIMATIC FEATURES OF THE ROMANIAN TERRITORY GENERATED BY THE ACTION OF MEDITERRANEAN CYCLONES

Luminița Garaba, Lucian Sfîcă [1]

Abstract. A dynamic factor with a determining influence on Romania's climate is the cyclonic activity within the Mediterranean Sea; the baric depressions that frequently form and evolve here towards the cyclone state are mobile most of the times, and their circulation is mostly towards and over the Balkan Peninsula and South-Eastern Europe. Their action significantly influences the climate in the South-Eastern part of the continent and brings about important spatial differences also between the different regions of Romania. The topic is intensely researched upon in Romanian climatology. In the present research, starting from synoptic materials at the continental level and from observations within 9 meteorological stations in Romania, the thermo-pluviometric impact of the Mediterranean cyclones was evaluated as per data gathered in the last decade. Moreover, the role of these cyclones as transmitting vectors of the subtropical influences on Romania's territory is evaluated.

Keywords: mediterranean cyclones, cyclones tracks, thermal anomalies, subtropical climate, Romania

1. Introduction

The Mediterranean cyclones were treated in climatologic literature mostly starting from the second part of the 20th century, along with recognizing them as being an important climatic factor for latent heat transportation and humidity at temperate latitudes. The humidity of the mobile depressions formed over the Mediterranean basin was noted mostly in the cold semester, when the polar front slides towards subtropical latitudes and generates high amounts of precipitations.

Significant contributions in order to identify the paths pursued by the Mediterranean cyclones were brought to fruition since 1882 by W. van Bebber, who classifies the trajectories of the cyclones which overpass Europe within the extreme months – January and July , some of these cyclones being Mediterranean, and by D. Radinovic, who in 1965 is preoccupied with the cyclones which overpass the Balkan Peninsula. A series of Romanian researchers contributed to the recognition of the meteorological and climatologic consequences of the Mediterranean cyclogenesis: the main types of circulation over Romania's territory are classified by N. Topor and C. Stoica (1965), among which the Southern, Mediterranean circulation. C. Șorodoc (1962) identifies cyclonic trajectories for Southern Europe, and E. Ion Bordei (1983) completes this research through classifying secondary trajectories according to local morphology as being ramifications of the major ones.

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A big amount of scientific contributions are brought about to complete the information with regards to the origin of Mediterranean cyclones (Campins et al. 2006, Draghici, 1983, Maheras et al. 2001, Trigo et al. 2002, Emanuel 2005), their trajectories (Șorodoc 1962, Alpert et al. 1990, Romem et al., 2007), the role of orography in modifying their trajectory (Struțu&Militaru, 1974, Tibaldi&Buzzi, 1983), their influence upon South-Eastern Europe's climate (Gogu, 2007, Maheras et al., 2001, Apostol, 2008) or the importance of Mediterranean cyclones in connection to extreme meteorological phenomena (Emanuel 2005).

The present study brings new information in what concerns the influence of Mediterranean cyclones within the last 10 years on the thermo-pluviometric characteristics of Romania's territory and it is attempted to evaluate the regional differences imposed by them and reflected through the appearance of climatic nuances – like the region of South-Western Romania with sub-Mediterranean influences (Geography of Romania, 1983).

2. Methodology aspects

The present study is based upon information archived in international climatic databases for the years between 2004 and 2013, on the basis of which our own databases were archived at the level of Europe's Mediterranean basin as well as at Romania's level.

Based on synoptic maps elaborated by Deutscher Wetterdienst between January 2004 and April 2013 every 6 hours (00.00, 06.00, 12.00, 18.00), we identified and recorded graphically the paths of every cyclon originating over the Mediterranean Sea, and those formed remotely and reactivated within this area, which later on either transgressed Romania, or had adjacent paths, which allowed the atmospheric fronts to influence the evolution of the weather within the Romanian territory. The software TNT MIPS was used to generate trajectories after introducing the precise locations of the cyclones, every 6 hours, using the Euclidian distance as method. In order to analyse and interpret later, we classified cyclones according to the month when they developped (or when the baric depression was within the smallest distance from the geometric centre of Romania – the point bearing the coordinates 45°N/25°E), and according to the direction in which the cyclones headed, respectively (using the paths indicated by C. Șorodoc 1962). Starting from the cartographic representations of the cyclones' trajectories between 2004-2013, we designed representations of the Mediterranean cyclones for each month, with a 2,5°grid.

For the period for which we had synoptic maps (2004-2013), we created a database with daily values recorded for the temperatures and precipitations, within 9 stations spread around the whole of Romania, inside and outside the Carpathian Mountains, within plateaux areas (Iasi, Sibiu), within hilly regions (Ramnicu-Valcea, Buzau, Cluj Napoca) and within plains (Arad, Bucuresti, Craiova), as well as within the tidal plain of the Black Sea (Constanța). The meteorological data for the 9 weather stations from Romania were taken from European Climate Assessment & Dataset (Klein Tank et al., 2002).

The mean daily temperature and daily amount of precipitation corresponding to the days in which the Mediterranean cyclone was at the shortest distance from the geometric centre of Romania was attributed for all the day during the period of cyclone activity, for the entire periods of time in which the meteorological influence of the cyclones' passage is significant for the Romanian territory was calculated, too. After computing the mean temperature and mean precipitation amount for whole the period, we calculated the anomalies of the cyclones' passages. Starting from these data, classified according to month and cyclonic path we could interpret the general influence and the seasonal or territorial variations produced by the Mediterranean cyclones over Romania's climate.

3. Results and discussions

3.1. Mediterranean Cyclones' Tracks

The tracks of Mediterranean cyclones were established according to the criteria of Șorodoc (1962), in order to compare our results with previous studies at the level of Romania's territory (Bordei, 1983).

Track 1. The cyclones which cross the Balkan Peninsula through the North-West and pass through the Pannonian Basin towards the Mid-Carpathians (Fig. 1) – where they contribute in certain conditions to heavy snow falls (Bednorz 2013) – are responsible for an appreciable amount of rain and snow falling in Western Romania, which they cross through the previous warm front, followed in some cases by cloud systems belonging to the terminal part of the cold front. It is very important to know that the cyclones which progress on this path get to Romania within 2-3 days from their formation within the Mediterranean Sea, moment in which the cyclogenetic processes are developed to their maximum state. These cyclones bear the most important role in excluding the Pannonian Basin from the extreme aridness.

Track 2a. These cyclones have as main characteristic the fact that they pass from the Adriatic Sea through the Gulf of Drin, to the Northern or Southern part of the Balkan Mountains until they reach the East-European Plain, these cyclones being frequently known in the Eastern and Southeastern parts of Romania, areas from which they head North avoiding the anti-cyclonal baric obstacle above the Black Sea. The homogeneity of the baric field above the continent throughout summer allows the tracks to head North, above the country's territory, while during the cold semester only the Dobrogea Plateau and the Bărăgan Plain are directly under the influence of the cyclone's center.

Track 2b. Although their center doesn't really reach Romania, the cyclones which form above the Aegean Sea and cross the Southeastern part of Europe bring important precipitations to the Romanian territory. Some of these cyclones stem from the ones generated in the Adriatic Sea, following the 2a track, but their heading South and their crossing the Aegean Sea in order to regain humidity turns them into track 2b-type of cyclones (Fig. 1).

The frontal ulterior activity determines changes of the meteorological elements especially in the Eastern part of the country, all the more so as the frequency of the cyclones is significantly high (24 in 2004-2013, among which 18 develop during the cold semester). In the cold semester some of these cyclones are responsible for generating blizzards in the Southeastern part of Romania (Balescu&Beșleagă, 1962, Gogu, 2007).

Track 4a. Comprises the cyclones which once arriving or being generated above the Adriatic Sea, head East either through the North or through the South of the Istrian Peninsula, cross the Dinaric Alps and then detour the Balkan Mountains in order to reach the Black Sea. Their main characteristic is that they cross the Carpathian-Balkan basin and often times they cross Romania.

3.2. Frequency of the Mediterranean Cyclones

Summing up the absolute frequencies for each of the trajectories of the cyclones which intersect Romania's territory (1, 2a, 2b and 4a), between January 2004 and April 2013, on a 2,5° side grid, we identified the most frequent tracks of the Mediterranean cyclones, as well as the seasonal and monthly variations of their localization.

The cold semester. This is the interval with the most intense cyclonal activity above the Mediterranean Sea, residing from the sliding of the Polar front and the intensification of the jet-stream at subtropical latitudes (Drăghici,1983). The months with the highest number of cyclones for the 10 years analysed are December and March (9-10 cyclones), which means that within these months, each year such cyclones cross the Southeastern part of Romania. Their high frequency is connected to the advance or regress of the planetary atmospheric front from the Mediterranean Basin.

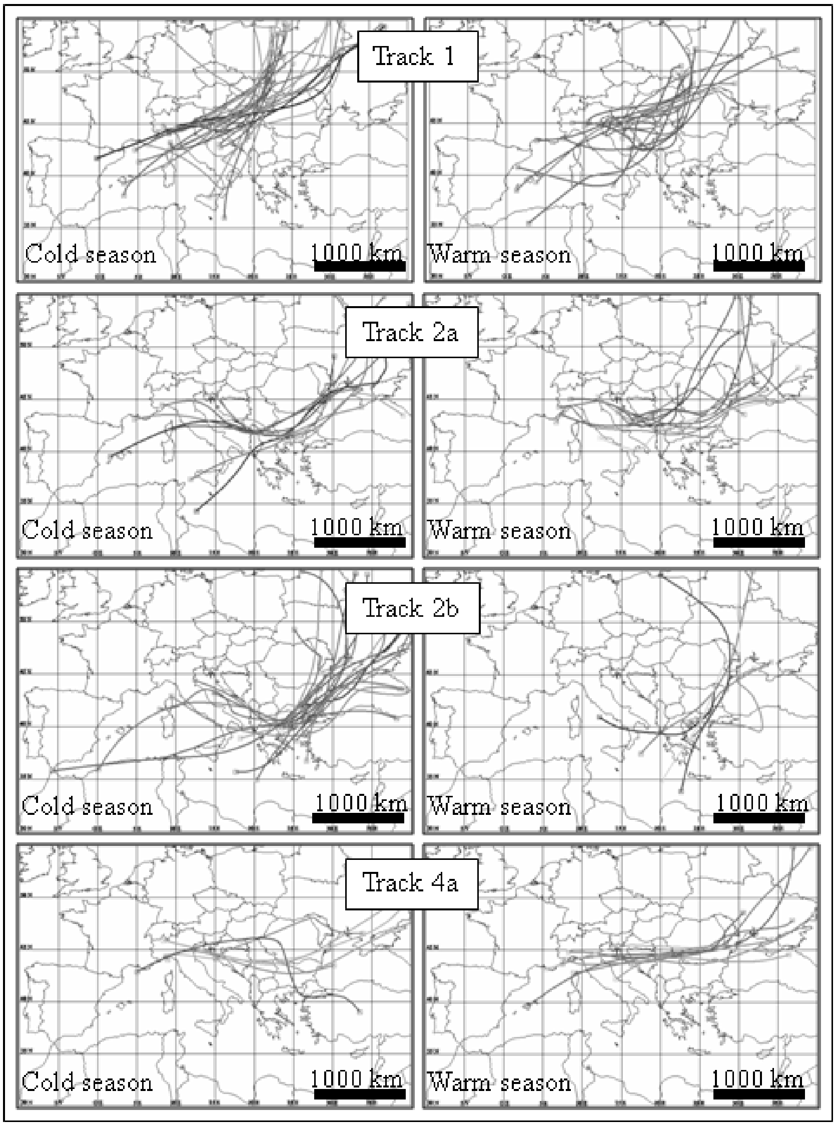

Figure 1: Main tracks of Mediterranean cyclones during the cold and warm season in Europe between 2004-2013

This could be an indicator of the climatic changes on a global scale which took place within the last decades, manifested in this case by a certain delay - from November to December - in the appearance of the planetary atmospheric front above the Mediterranean Basin. When the alternative invasions of polar and tropical air masses happen in the subtropical European area of the Western and central part of the Mediterranean Basin, the cyclones move to the East, modifying their direction towards SW-NE, until they occlude in the Northern part of Europe. The most frequent tracks are directed either on the path consisting of Lombardy – The Adriatic Sea – the Pannonic Plain – The Bielorussian Plain – The Baltic Sea, or on the path The Adriatic Sea – The Albanian Plain – The Balkan Peninsula – the Western Black Sea – The Russian Plain (Fig. 2).

The cyclonic trajectories are conditioned by the baric elevation level, and most of all by the baric centres from the lower troposphere which in the cold semester create blockages to the Mediterranean mobile cyclones. The anticyclone which forms during winter season in the Eastern part of the continent, with significant vertical development, forces the cyclones which arrived above the Aegean Sea and the Western Balkan Peninsula to move to the North-East and North (Tibaldi&Buzzi, 1983). Similarly, the Scandinavian Anticyclone and the high-pressured that develops between the Siberian Anticyclone and the Anticyclone of the Azores, have the ability to imprint a trajectory of the type WSW-ENE to the Mediterranean cyclones, which in March cross mostly the Southern part of Romania. The months with low frequencies (1-4 cyclones) of the Mediterranean cyclones (October, January, February) are the same as those in which the continental frontal activity superimposes with the temperate latitudes or subtropical latitudes (Fig. 2).

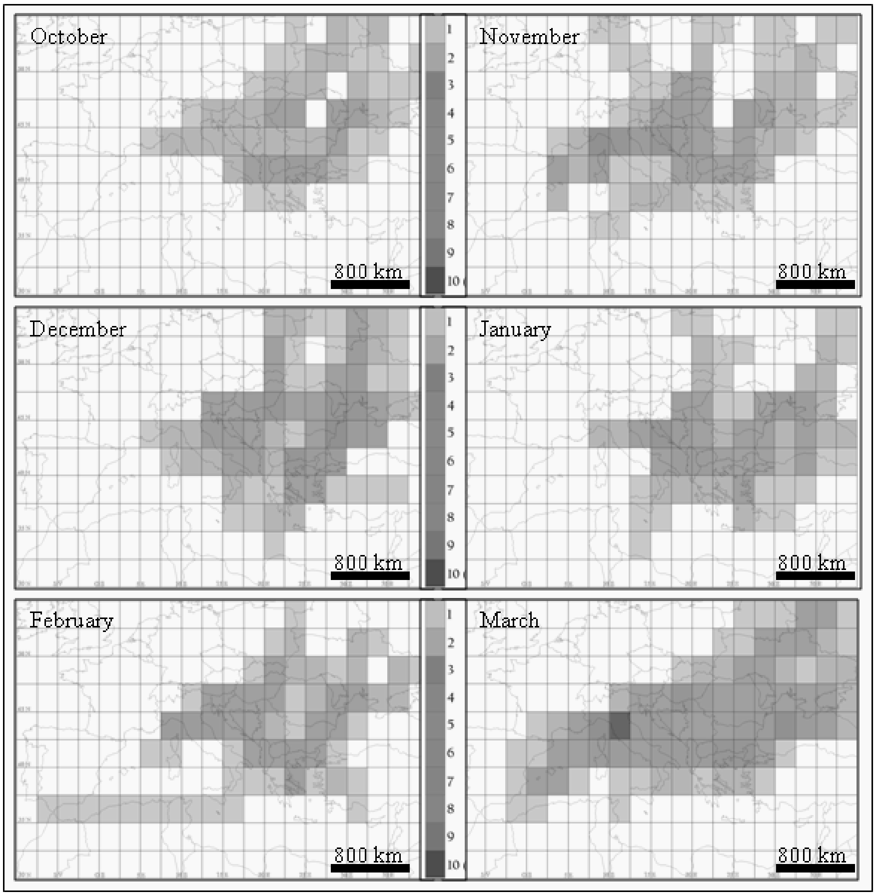

Figure 2: Monthly frequency of the Mediteranean cyclones centers in Europe during the cold season for the 2004-2013

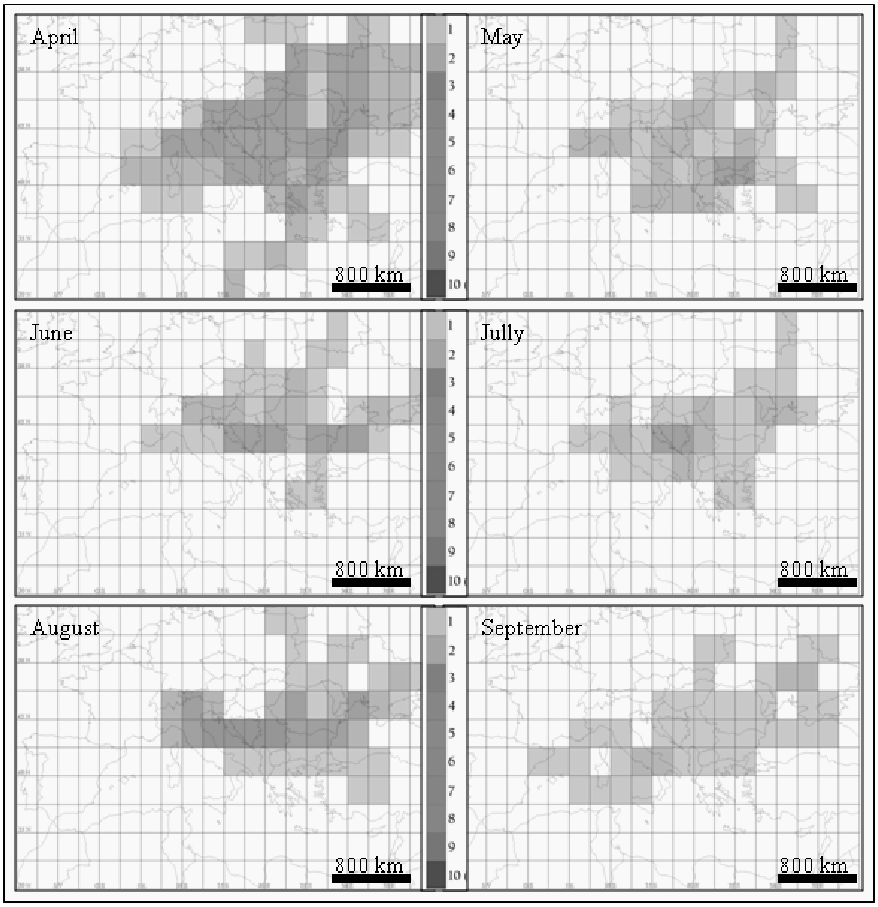

Figure 3: Monthly frequency of the Mediteranean cyclones' centers in Europe during the warm season for the 2004-2013

The warm semester . On the background of a more homogenous baric field above the Mediterranean Sea, the cyclones that are formed being mostly of thermal origin (Trigo et al., 2002), with low vertical development and low in intensity (as per the horizontal baric gradient). The months in which the frequency of the cyclones can reach 5-6 cyclones are April and August. One can notice the paths followed by the Mediterranean basins, visible mostly in April, when Romania's territory is passed-by or crossed through its extreme Western or South-Eastern parts, the highest frequency in this month being connected to the belated retraction of the Polar atmospheric front towards the North, from the Mediterranean Basin (Fig. 3).

3.3. The precipitations generated by the mediterranean cyclones depending on their trajectories

The quantity of precipitations noted for Romania's territory after the passage of the cyclones of Mediterranean origin depends on the track which they follow in the South-Eastern part of Europe. The trajectories 1 and 2b are those which have the highest impact on Romania, track 1 mostly for Western Romania and Northwestern Romania, and track 2b mostly for the extra-Carpathian areas.

Track 1. The importance in what concerns of the Mediterranean cyclones which evolve on this trajectory is rising up to 20% of the total amount of precipitations in the Western Plain and the Transylvanian Basin, during the months with significant cyclogenetic activity (March, April, Mai). The same reason explains the volume of Mediterranean precipitations in November and December, limited to Western Romania. This trajectory is the one that prevails to the maximum amount of precipitations in western Romania. In our oppinion a major part of the annual precipitation amount from Stâna de Vale, the wettest romanian weather station (Romania’s Climate, 2008), is generated by the sliding of the mediterranean cyclone fronts evolving on track 1 along the western slopes of the Vlădeasa Mountains, which amplifies the orographic processes on the slopes exposed to advection where the meteorological station of Stâna de Vale is situated. These cyclones are those which generate the second maximum during the autumn season in the Pannonic Basin (Weischet&Endlicher, 2000), which is highly visible as per data from Arad (Fig. 4).

Track 2a. From the point of view of precipitations, the trajectory 2a has a significant input mostly in April, when it determines 20-30% of the precipitations in Romania, this being the month with the highest frequency of mobile cyclones on this track. A second maximum percentage is noted in September-October, without surpassing 16% of the precipitations which happened on the background of the low-intensity cyclogenesis. The annual maximum contribution to the quantity of precipitations of these cyclones is noted in the Southern part of the country, where it reaches 20% (Gogu, 2007).

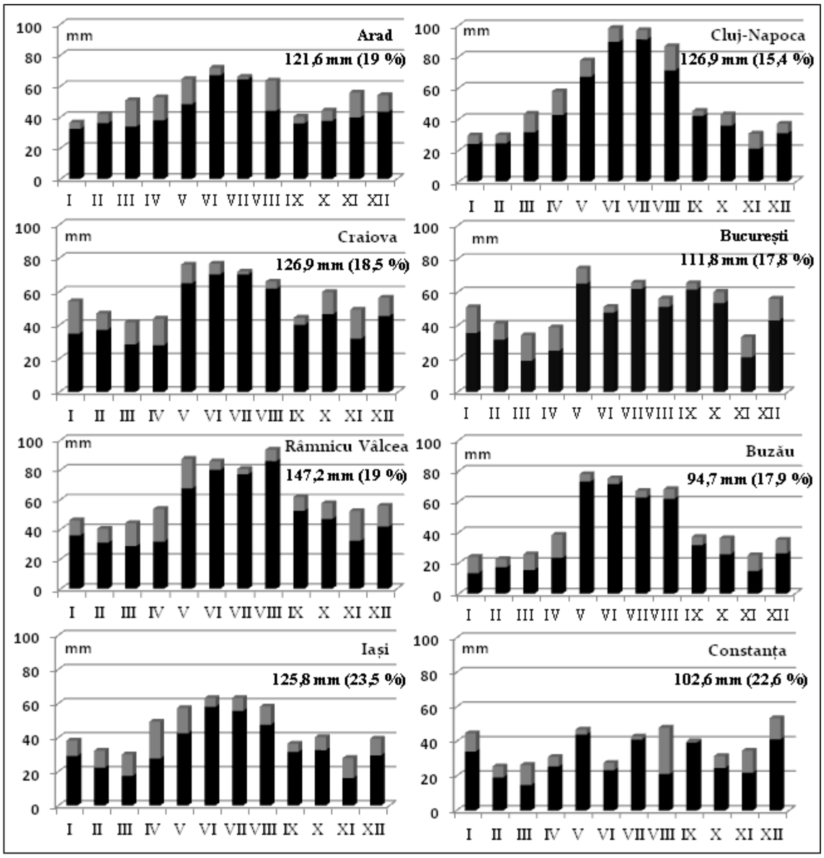

Figure 4: The monthly (grey bar) and annual (percent) amount of precipitation generated by the mediterranean cyclones in Romania (2004-2013)

Track 2b. It is the most pluviogenous for Romania's territory, among all transbalkan trajectories of Mediterranean cyclones. The cyclones originating in the central part of the Mediterranean Basin, charged in the Aegean Sea contribute constantly throughout the year to the average precipitations per month. The Aegean Sea represents one of the main cyclogenetic regions of the Mediterranean Basin (Lionello et al., 2001a, Maheras et al., 2001). Except for July-September when cyclogenesis decreases in intensity, during all the other months, the cyclones of the type 2b reach and frequently go over 10-20% and even 30% of the monthly precipitations, mostly at the meteorological stations in the Southern part of Romania, and even more frequently in the extra-Carpathian region. The cyclones which develop on the track 2b have a significant pluviometric input especially in January in the South and East of the Carpathians, month in which their frequency is extreme (Alpert et. al., 1990). Through their pluviometric input, the Mediterranean cyclones which evolve on track 2b diminish the hidric aridity conditions from the extra-Carpathian regions of Romania, thus diminishing the climatic excessiveness from Bărăgan and Dobrogea (Ion-Bordei, 1983).

Track 4a. The Mediterranean cyclones which move on this trajectory are reduced in number, reason for which their percentage with regards to pluviometric average values doesn't go over 10-11% but it is present throughout the year.

The total amount of precipitations generated by the Mediterranean cyclones. This picture confirms the partial results obtained after analysing the pluviometric effects of each cyclones' type: the dynamic Mediterranean precipitations are constant throughout the year, in all of Romania's regions (inside and outside the Carpathians, close and remotely from the Black Sea and the Mediterranean Sea).

The Mediterranean cyclones determine up to 126,9 mm/year in Craiova (18,5% from the annual amount) in the Southwestern part of Romania 147,2 mm/year in Râmnicu Vâlcea, in the submontane area of Southern Carpathians (19%) due to orographic convection, and in the Eastern part of Romania where the annual average values are smaller than 500-600 mm, the Mediterranean input is a quarter of this volume; 102,6 mm/y in Constanța, in the Black Sea Basin (22,6) and even more, 125,8 in Iași (23,5%). The highest amount outside the Carpathians diminishes the pluviometric contrast between the Eastern versants and Western versants of the Oriental Carpathians (Apostol, 2008).

The months with the greatest Mediterranean contribution are November – December, and March – May, periods in which the contact between polar air masses and tropical air masses takes place at temperate latitudes, including Romania. Calculating an average value for the precipitations of Mediterranean origin during these months (March, April, May, November, December) and connecting it to the monthly average values, the contribution of the Mediterranean basins reaches 31,1% in Râmnicu Vâlcea and 34,7% in Iași. Therefore, in the Moldavian Plateau, in Northeastern Romania, the precipitations of dynamic origin represent a third of the total during the months with maximum cyclonic activity; for the soil, vegetation and crops, this high amount is extremely important, diminishing the climatic continentalism with which we associate this region of Romania.

3.4. The Average Temperature Anomalies Determined By The Mediterranean Cyclones

From the thermal point of view the anomalies are determined by the cyclone's centre passage through the Northwest or Southeast of Romania, which places Romania especially in the warm and cold sector respectively, of these cyclones.

The characteristics of the cyclones which cross Western Romania, heading to the Northern and Central Europe, are the over-average temperatures, when we compare them to the average daily values. In order to simplify the situation, we took into account the air temperature during the days in which the center of the basins was at the smallest distance as compared to the geometrical centre of Romania (46°N, 25°E), and the average temperature on the same dates in 2004-2013. The differences were positive for all months and all meteorological stations taken into consideration (Fig. 5).

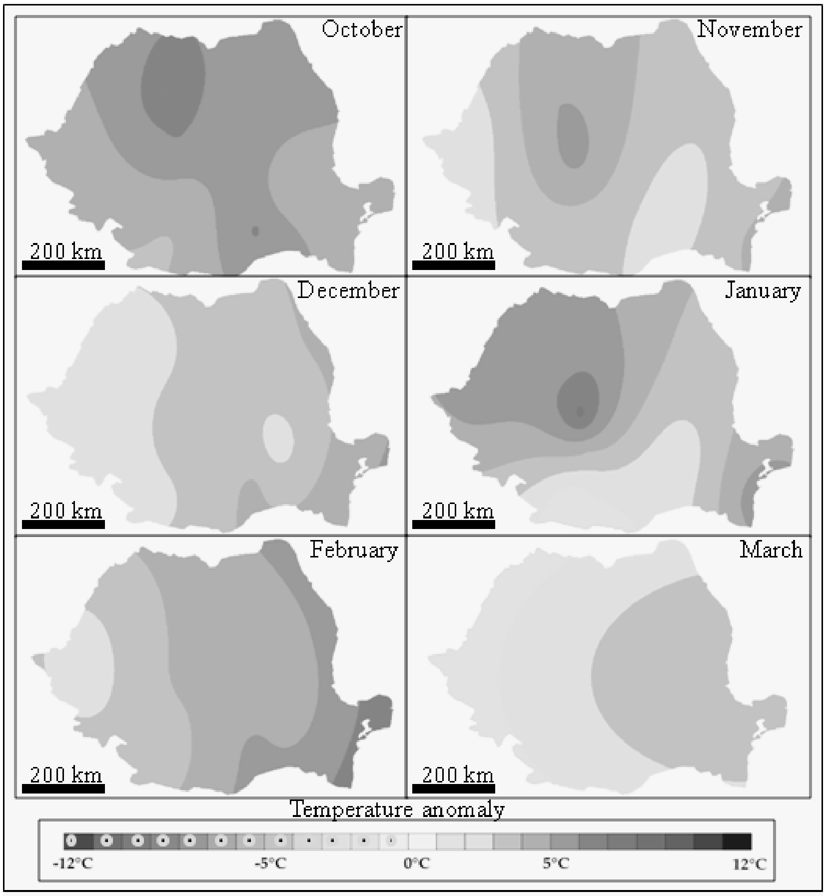

Figure 5: Temperature anomaly generated by the Mediterranean cyclones having The track 1 in Romania during cold season (2004-2013)

This happens because the air masses head forward from the Southern part of the continent on the anterior side of the cyclones, the development of atmospheric warm fronts being followed by the installation in Romania of air masses with thermal and baric subtropical characteristics. The evolution with time of the anomalies in temperature shows the highest values for October, due to the high thermal contrast between the active surfaces from Northern and Eastern Europe. In Northwestern Romania (crossed mostly either by the basin's centre, or by the anterior warm front), they can rise beyond 6-7°C and for the rest of the territory, the recorded temperatures are 4 to 6°C higher then the average value. Most of the time these high values are responsible for the massive warming episodes in Romania.

Important temperature anomalies take place also in November and January, mostly in the Transylvanian Basin and in Northwestern Romania. An additional factor to the proximity from the cyclonic centre is represented by the adiabatic processes of foehn; these lead to such anomalies which are superior to the exterior of the Carpathian arch(Apostol&Sfîcă, 2013). Moreover, the Black Sea's Basin bears positive anomalies, on the background of warm air advections from the neighbour seas (The Black Sea, The Aegean Sea, The Mediterranean Sea). In February the temperature anomalies are notable, especially in the Eastern half of Romania, with values which start from 4°C and go beyond 6°C in The Dobrogea Plateau and The Danube Delta.

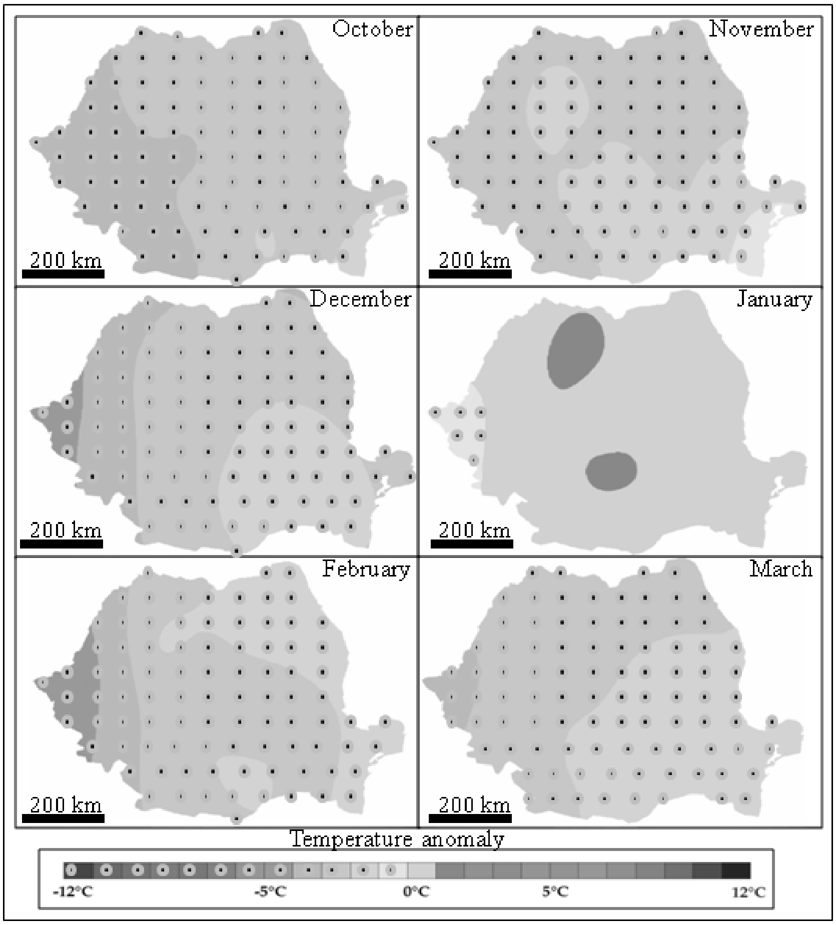

Figure 6: Temperature anomaly generated by the Mediterranean cyclones with track 2a, 2b, 4a in Romania during warm season (2004-2013)

Tracks 2a, 2b 4a. The cyclonic trajectories which cross the Balkan Peninsula with different directions (W-E, SW-NE or S-N) have in common only some thermal patterns, because the subsequent cold fronts are those who traverse Romania's territory. The temperature anomalies are generally speaking negative, and their value increases from East to West. This is a consequence of the Polar air masses originating from above the Arctic Ocean and Northern Europe and invading the Eastern side of an altitude ridge or the North Atlantic Ocean (Apostol, 2008), these types of passages being oftentimes associated with the polar circulations of masses within Romania's territory. The cold air crosses the Polish Plain and the Pannonian Basin and reaches Western Romania without encountering any obstacles; here the recorded temperatures are 1 to 5°C more reduced than the daily average value for this period of time.

In Eastern and Southeastern Romania, regions which are in most cases within the passage direction of the Mediterranean basins, the fronts can alternate over Dobrogea, The Plain of Bărăgan and the Southern part of the Moldavian Plateau, thus reducing the anomalies to values of -1...-3°C. In addition, the Carpathians are a strong barrier for the cold air masses, which are dense and with seldom vertical development and the Polar air can reach Southeastern Romania losing some of its initial characteristics.

January is the only month during the cold season in which the temperatures rise up to 1-2°C in Romania due to the cyclonic activity of Southeastern Europe. The phenomenon can be explained due to the obtrusion of tropical air masses through the anterior side of the cyclones, from the Near and Middle East, these regions being in an area with minimum baric thermal values. The rebirth of cyclones above the Black Sea has significant input, too, which by processes of condensation generates rises in temperature.

4. Conclusions

By putting together the analysed data, one can affirm that no matter the path followed – either through the Western part, or through the Southern and Southeastern part of Romania – the Mediterranean cyclones generate significant pluviometric and thermal effects in the inferior troposphere, in South-Eastern Europe. The daily temperature anomalies are between -13°C and +12°C. The Southern part of Romania (Banat, Transylvania and Oltenia) is the most sensitive to dynamic thermal variations, either positive or negative; but, from the point of view of precipitations, the Eastern and Southeastern parts of Romania are the receivers of significant absolute and percentage amounts which actually define the climate in these regions, weakening the climate continentality and allowing the progress of the hydrologic cycle throughout the year, with beneficial effects upon the vegetative cycle.

We can also note recent mutations which also take place in Romania that happen on the background of global climate changes (Dragoă & Kucsicsa, 2011). These mutations consist of a slight change in what concerns the month with the highest cyclonic frequency – November to December, as well as of a decreased flow of precipitations brought by the Mediterranean cyclones (15-20% of the annual total as per our estimations) as compared to previous similar estimations (25-35% of the annual total amount as per Ecaterina Ion-Bordei, 1983) which can indicate a different trend in recent climate changes. It is well-known that the number of Mediterranean cyclones in the Eastern Mediterranean Sea is decreasing during the cold semester (Maheras et. al., 2001a), which can be connected to the increasingly high drought periods of time in different areas of the Balkan Peninsula (Rajic&Bezdan, 2012) and with the decreased precipitations in the Mediterranean Basin (Dünkeloh&Jacobeit, 2003).

It is noted also that the climatic impact of these cyclones has no different regional values from the pluviometric point of view at the level of our country. In this respect, as long as these cyclones represent the main vector of transmitting the subtropical influences over Romania's territory, our results are not an argument for delineating a distinct region bearing sub-Mediterranean influences in Romania. In this matter, the region with so-called sub-Mediterranean influences in Southwestern Romania (Geography of Romania, 1983) is nothing less than a region with a strong orographic character, the spreading of subtropical vegetation resulting directly from the orographic shelter of the Romanian Southwestern Carpathians, as opposed to the cold Polar or ultra-Polar air advections.

To sum up from a dynamic point of view, the Southwestern part of Romania is as sub-Mediterranean as the rest of the country.

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