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HAZARDS INDUCED IN EASTERN ROMANIA BY MEDITERRANEAN RETROGRADE CYCLONES. CASE STUDY FOR THE 22-27 JULY 2008 INTERVAL.

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ABSTRACT - The European continent is not spared from natural disasters and a very large number of those are caused by temperate latitude cyclones. The Mediterranean area is among the most affected and a major role in their initiation is held by the Mediterranean cyclones, through the weather phenomena with catastrophic effects they induce many a time. A very large number of the meteo-climatic disasters recorded in Romania, like the abundant rainfalls, followed by floods, the storms and the heavy blizzards, the droughts and in some cases the land slides are tightly connected to the Mediterranean cyclones, especially those evolving retrogradely. The rainy spell of 22 - 27 July 2008 was caused by the activity of a retrograde cyclone of Mediterranean origin, and the disasters it triggered in the east and north-east of the Romanian territory enlist it as one of the strongest, generating one of the rainiest spells ever recorded in Romania.

Key words: Mediterranean retrograde cyclone, floods, meteo-climatic hazard

1. Introduction

Researchers have demonstrated ever since the last decades of the 19th century that the temperate latitude cyclones aggregate the efforts of two air mass types (the cold ones pulsating towards southern latitudes and the warm ones pulsating towards northern latitudes) for reaching thermal and pressure balance, rallying those masses in huge vertical vortices whose role is to couple the motion, acting as real mechanisms for the energetic transfer between the various parts of the troposphere.

In the geographic environment of southern and south-eastern Europe, the ***Mediterranean cyclones*** play a very important part in the aspect and evolution of the weather, as well as in settling the climatic characteristics. Knowing those cyclones has improved in step with the meteorological infrastructure at

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international level necessary to identify and classify the Mediterranean cyclogenetic processes in the context of the general atmospheric circulation.

The Mediterranean cyclones (resulted after the penetration in the Mediterranean of the cyclonic disturbances from the Atlantic through the Gulf of Biscaya, either formed as secondary cyclones of the vast low pressure area from Iceland and the North Sea, or born due to the movement of the north-African low pressure nuclei towards the Mediterranean basin) are the pressure systems with the highest hydric potential, generating rather heavy precipitation, either in south-western, western, central and northern Romania, or in the south, the east and sometimes the centre, function of the followed trajectory.

However the Mediterranean retrograde cyclones are accountable for the most severe weather developments, more precisely those cyclones which, having reached the Black Sea basin recharge with moisture and evolve in a different direction, heading inversely, east to west, instead of following the classical west-east track, a phenomenon meteorology calls "retrogradation". The occurrences that they generate are more intense also because of the impact of the orographic barrier posed by the Eastern Carpathians- one of the best known cases being that from May 1970 when the most severe floods in the 20th century unfolded.

The study of the cyclones with a retrograde motion has practically been simultaneous with the emergence of meteorology as a modern science. In the first phase of the researches, Exner (1913), Bjerknes and Palmen (1937) have only reported cases of abnormal motion of certain European cyclones, on the basis of ground temperature and wind data, because upper air maps did not exist at the time yet. In and after 1935 – 1940 Bjerknes, Mildner, Palmen and Weickmann (1939), but also Hromov (1947) attempted to integrate the cyclones with a retrograde motion in the broader context of mass and energy transfer from one latitude to another. As H. P. Pogosian's and N. L. Tabarovschi's advective-dynamic theory surfaced in 1948 and was very rapidly improved by I. A. Kibel (1949) researchers also reinterpreted the causes of the formation of retrograde cyclones.

In 1958, A. Doneaud for the first time in Romania made a theoretical demonstration in this sense. His conclusion was that major and very fast changes in the structure of the thermo-baric field are in direct connection with cyclones turning retrograde from their potentially normal trajectory. He classified the retrograde low pressure structures by three types:

a) type I: a single rotation; a lifetime of 2-3 days at most;
b) type II: two rotations and a lifetime from 2-3 days to 5-6 days;
c) type III: a circulation to the south-west, occluding 1 to 3 days from formation or sometimes becoming normal, with a displacement towards the south-east or east.

Thorough researches on this category of peculiar interest to our country were carried out by Struțu M., Militaru F. and Stoica (1974). The mentioned researchers attempted to snapshoot the interference of the scrutinized cyclones with the major relief in Romania. In south-eastern Romania, the Black Sea basin and the lower Danube area ensure extremely favourable conditions to cyclones to regenerate and enhance, when the area is invaded by cold air inducing a thermal contrast of 8 to 10°C within 1000 km. At the same time, favourable conditions occur in the area to the intensification of retrograde cyclones. On the other hand, the natural barrier of the Carpathians, especially of the Eastern Carpathians, is an obstacle to the evolution of these depressions, once their heading changes. Ascending flows act ahead of the mountain chain, in circumstances more than favourable, which is due to the convergence of the air flows. These flows are an important regenerating factor for the cyclonic centres undergoing a phase previous to the occlusion one.

The most favourable conditions for inducing a retrograde motion are met in the case of the cyclones that follow those trajectories that favour their displacing above the Black Sea. This paper monitored the activity of these cyclones, selecting the one vivid from 22 to 27 July 2008, whose evolution triggered consequences of the most severe in the eastern part of Romania.

2. The rainy interval 22 - 27 July 2008 – Case study

The synoptic and mesoscale evaluation of this severe weather case was performed by using the analyses of the ECMWF global numerical model and of the ALADIN limited area one, along with satellite (Meteosat 9) and (Doppler) radar products, with frontal analyses (SatRep) and with data supplied by the weather stations. There were also used the daily and monthly weather bulletins elaborated at the National Meteorological Administration.

2. 1. General characteristics

July 2008 was warmer than usual in most of the country, with a noticeable brief sultry spell (7 – 8 July) and most of all, it yielded plentiful precipitation. In this latter respect, the 22-27 July stands out through its enhanced instability, acting especially in the northern and north-eastern areas. Rain fell torrentially and in large amounts, which caused flooding in Moldavia, Transylvania and Maramures. Water amounts exceeded 40 mm, narrowly 60 mm in Maramures, Crisana and eastern Banat and were even in excess of 100 mm in Moldavia. It lightened frequently and there were numerous hail events and squalls.

2. 2. Synoptic and mesoscale analysis

In the interval 20-21 July 2008, the Azores High was centred over the British Archipelago. This enabled an advection of humid and cold ocean air on its front side towards the central-western Mediterranean basin, with the thermal trough axis perpendicular to the alpine arch (a peculiarity favouring shelter cyclogenesis). The pressure field in the south of Europe (the Mediterranean basin included) was relatively low, favouring the emergence of young cyclones, whereas northern Europe was influenced by a vast cyclonic area of Icelandic origin (Fig. 1).

In the mean troposphere warm ridges were present to support the ground level anticyclones that were flanking the Europe, west and east; the central European teritory was dominated by a trough, with its north-east to south-west axis, which enabled south-westerly circulation over Romania and thus additional ascending to the warm air from the Mediterranean basin (Fig. 2).

This distribution of the pressure all along the tropospheric column (the level of 300 hPa included) favoured the emergence of a young cyclone above the Mediterranean, which was going to reach the latitude of our country starting 22 July 2008, coupled with the advance of the Azores High ridge towards the east of the continent, tending to build up a high pressure ridge through connecting with the east-European high pressure system (Fig. 3).

Given the sharp thermal asymmetry, remarkable at the level of 850 hPa between the trpical air mass from the warm sector of the cyclone (16…17°C) and the Polar-continental one advected in its hind section (2…4°C) (Fig. 4a), the weather events were extremely violent, with large precipitation amounts, especially in the western half of the country, in the evening of 22 July and the ensuing night, as the cold front entered the Romanian territory from the south-west (Fig. 4b).

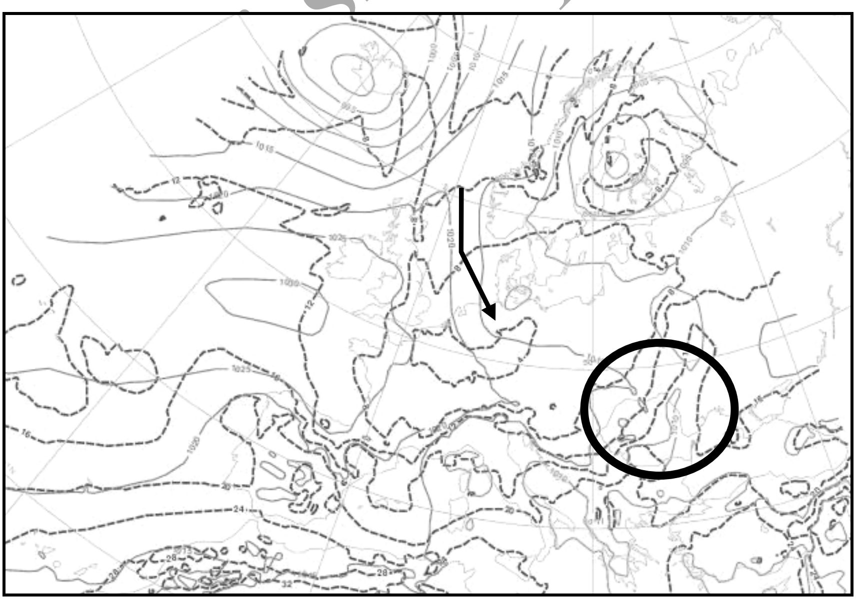


Figure 1. Sea level pressure and temperature at 850hPa, ECMWF numerical model analysis; 21 July 2008, 18:00 UTC.

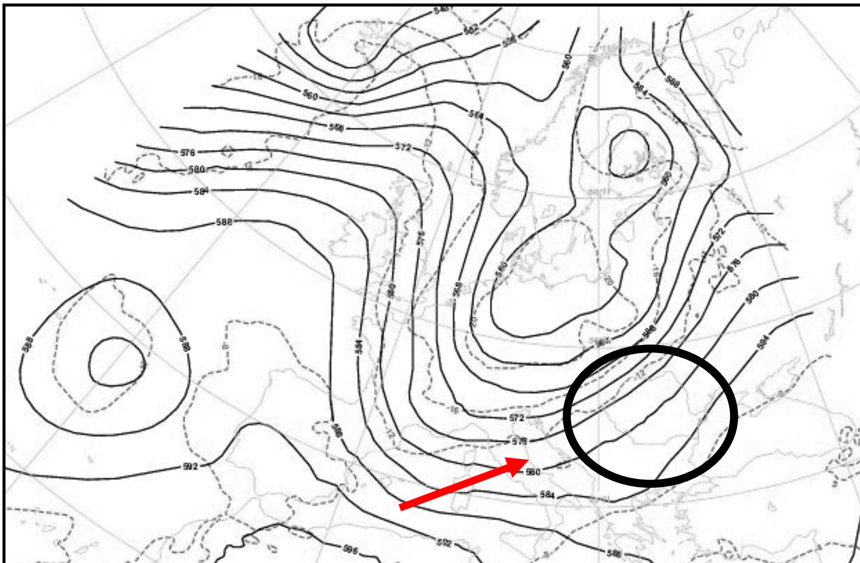


Figure 2. Geopotential and temperature at 500 hPa, ECMWF numerical model analysis; 21 July 2008, 18:00 UTC.

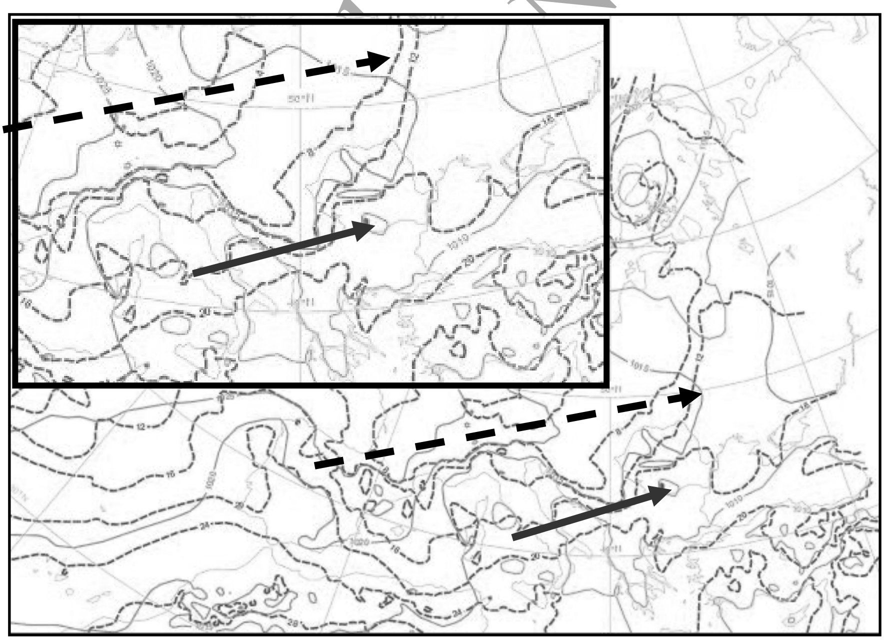
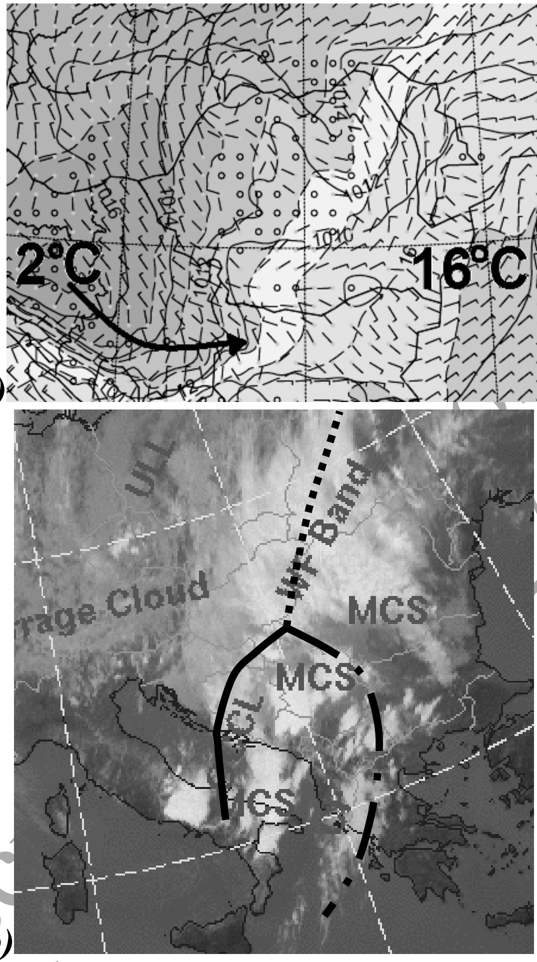


Figure 3. Sea level pressure and temperature at 850hPa, ECMWF numerical model analysis; 22 July 2008, 00:00 UTC.



a) b)

Figure 4. **a)** Sea level pressure, temperature at 850 hPa and 10-m wind, ALADIN numerical model analysis, 22 July 2008, 18:00 UTC (left);
b) SatRep frontal analysis, 22 July 2008, 12:00 UTC (right).

The intensification of the high pressure belt over most of the continent determined a blocking in the cyclonic vortex's natural evolution towards east, and reorientation of its trajectory towards the north-east and north of our country. In the altitude, a low pressure nucleus isolated itself, being remarkably active, especially in the mean and high troposphere (Figs. 5a, b). As regards the activity from the mean and high levels, a tendency of the monitored vortex to move retrogradely was also obvious, as a result of the blocking exerted by the ridge from the eastern-south-eastern border of Europe, that had expanded significantly northwards, from the eastern half of the Black Sea basin to the central part of the Russian Plain.

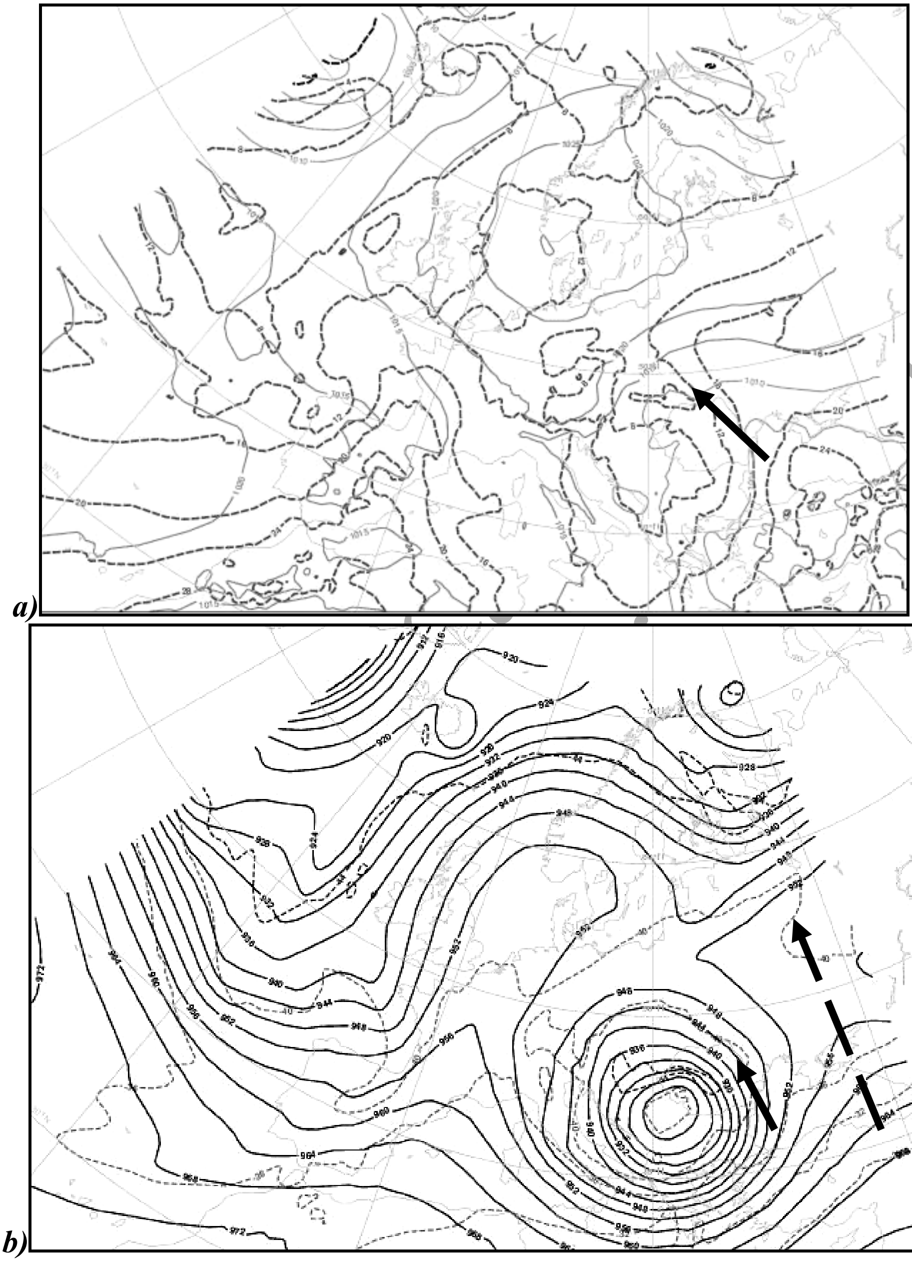


Figure 5. **a)** ECMWF numerical model analysis as of 24 July 2008, 00:00 UTC: Sea level pressure and temperature at 850 hPa; **b)** ECMWF numerical model analysis as of 24 July 2008, 00:00 UTC: Geopotential and temperature at 300 hPa.

Given the continuous accumulation of energy within this quasi-stationary vortex, owed to the transport of air rich with water vapours from the western basin of the Black Sea on the front side of the vortex, the only possible evolution was for the vortex to deepen and increase its spinning speed.

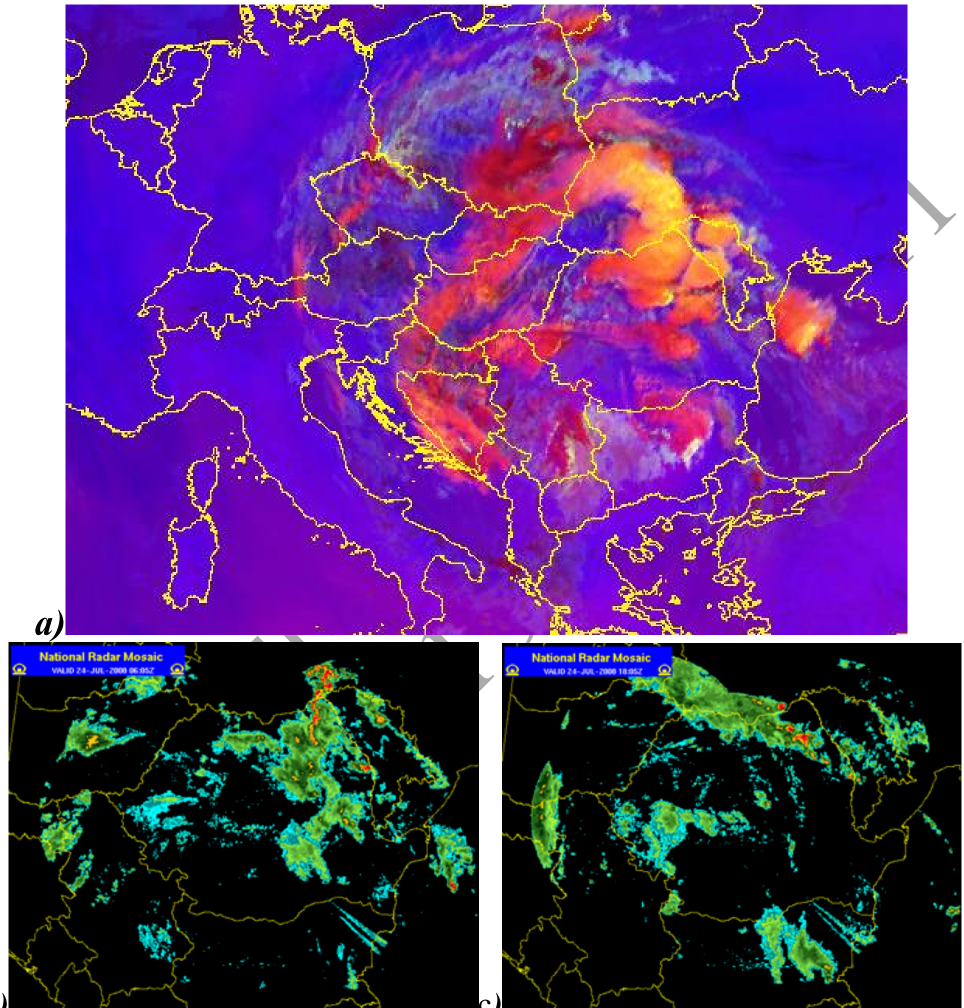


Figure 6. RGB WV 6.2 – WV 7.3, IR 3.9 – IR 10.8, NIR 1.6 – VIS 0.6, 24 July 2008, 06:00 UTC **(a)** Reflectivity – National Radar Mosaic, 24 July 2008, 06:00 UTC **(b)** and 24 July 2008, 18:00 UTC **(c)**.

Consequently the convective processes along the Gulf of Odessa – north-western Black Sea- northern Romanian border- south-western Ukraine line enhanced, as it is also shown by the high CAPE (Convective Available Potential Energy) values and those of the moisture convergence (MOCON), identifiable in the above mentioned area.

The convective systems accountable for the severe weather occurrences from the northern and north-eastern parts of our country constituted in ***supercellular systems (displaying very high reflectivity values in the radar imagery and typical structures in the satellite imagery)*** which developed one behind the other, approximately in the same direction (Figs. 6a, b and c). The presence of the orographic barrier in their moving direction induced supplementary forcing, implicitly leading to the enhancement of the phenomena on the northern slopes of the Eastern Carpathians.

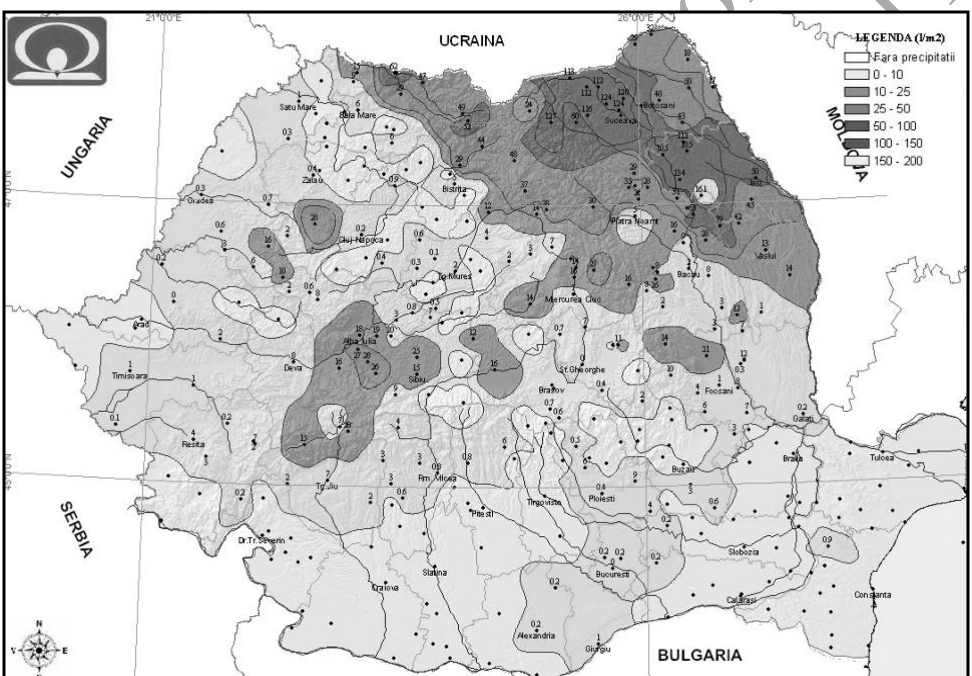


Figure 7. Precipitation amounts recorded from 24 July 2008, at 06:00 UTC, to 25 July 2008 at 06:00 UTC (NMA data).

Both the record water amounts, in a number of localities in excess of 100 mm, reaching even 160 mm (Fig. 7), and the other phenomena associated to the atmospheric instability (squall-like wind gusts and hail) led to amplified damage in the northern half of Moldavia, and were somewhat less destructive in Maramures and north-western Transylvania. As regards the correct magnitude of the consequences of the events from 24 – 25 July 2008, one must also take into account the weather situations at least equally severe from the western half of Ukraine and from the Republic of Moldova.

During the following 48 hours (i.e. until 27 July), the low pressure nucleus slightly moved towards the western basin of the Black Sea, gradually occluding in the absence of conditions necessary for the preservation or deepening of the thermal asymmetry. Instability occurrences were still present in the interval, but far less severe, however striking in comparison to those from a usual interval, again in northern Romania, but mostly in the countries neighbouring ours to the north and north-east, aggravating through propagation the damage recorded in that third 10-day period of July 2008.

Precipitation amounts recorded at the weather and hydrological stations, as well as data supplied by the rain measurement points in the last two days of the interval of concern ascertain the decline of the phenomena associated with the atmospheric instability, being however reported large water amounts in 24 hours (narrowly in excess of 50 mm) in comparison to the climatological norms and mostly taking into account the pre-existing situation.

As a conclusion, the above presented highlight that the severity of the phenomena is justified by the pressure filed both at ground level and in the higher layers of the troposphere, i.e. by the presence of a retrograde cyclonic nucleus in the eastern basin of the Black Sea which favoured the transport of the very moist air advected on the front side of the nucleus in the altitude and the vorticity advection on its hind side. This coupling made the air mass strongly unstable, deepened the vortex and preserved it for more days in a row.

3. Socio-economic consequences and echoes of the events

In the interval under scrutiny (22 – 27 July 2008), it was noteworthy that 414 localities from seven counties were affected in Romania and most of all that seven lives were lost. Destroyed or damaged were 7 100 houses and 1 997 households, 73,730 ha of agricultural land, 76 socio-economic units and an important share of the infrastructure (numerous roads were rendered impassable after bridges were torn and damages were spotted in the asphalt).

In the analysed case the National Meteorological Administration issued five yellow code warnings and an orange code one. At the same time the National Institute for Hydrology and Water Management issued even the red code for Prut and Siret rivers (in Suceava, Botosani, Iasi and Neamt counties), besides the numerous yellow and orange code warnings. In the basins of the above mentioned rivers important discharge increases were recorded, even reaching historical discharge levels on Prut rivers, with the water exceeding the danger and flood levels.

The flooded areas, both in Romania and in the neighbouring countries (the Republic of Moldavia and Ukraine) became available for study through processing various images, mainly by the National Meteorological Administration, in cooperation with the Romanian Space Agency (Fig. 8), by also by NASA, which made a brief presentation of the floods in East Europe in its natural hazards section from “Earth Observatory”.

Figure 8. Flooded areas - Radauti Prut commune territory, TerraSAR-X (3-m spatial resolution), 29 July 2008.

For almost two weeks the events connected to the described floods were headlines in newspapers and news bulletins broadcast on the radio or at the TV: ***DISASTER AFTER RAINS OF BIBLICAL MAGNITUDE*** – THE CHRONIC OF THE LATEST FORECAST FLOOD: “*Fresh torrential rainfalls are again forecast for the next week in the north of the country” (“*Jurnalul National”, 2 August 2008); *“The red code for floods is extended for Siret and Prut rivers”* (“Antena 3” news, 28 July 2008) etc.

4. Conclusions

The Mediterranean cyclones are the pressure structures with the highest moisture potential, generating the most abundant precipitation within the Romanian geographic environment, the Mediterranean retrograde cyclones being accountable for the most severe weather developments.

Besides the circulation at synoptic scale, major influences on the air circulation above Romania are exerted by the Carpathian Mountains, as they represent an orographic disturbance, by the Black Sea as a thermal disturbance and by the thermal effects of radiative heating and cooling in the vicinity of the terrestrial surface. Knowing all the thermally or orographically-induced peculiarities across the Romanian territory, especially when a Mediterranean retrograde cyclone evolves, is of deep interest to the forecaster for a correct estimation of the weather evolution in Romania.

To conclude with, it is remarkable that, as it was shown, during the activity of such a cyclone, precipitation amounts may exceed even 100 mm in 24 hours, with accompanying extreme weather events, especially in the areas from eastern Romania, as was the case in the 22 -27 July 2008 interval.

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