*Fenomene şi procese climatice de risc*

# THE 22-27 JULY 2008 SEVERE WEATHER EVENT – AN EXAMPLE OF RETROGRADE MEDITERRANEAN CYCLONE FLOOD

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**ABSTRACT. –The 22-27 July 2008 severe weather event – an example of retrograde Mediterranean cyclic flood.** The 22-27 July heavy precipitation events that affected the north-eastern part of Romania are described here in terms of meteorological analysis. The Romanian territory is affected by the presence of Mediterranean cyclones transporting moist and warm air from the Mediterranean Sea basin. In certain meteorological conditions, the Mediterranean Lows moving towards eastern Europe get a retrograde movement over the Black Sea and thus contribute to the increased moisture content of the forming convective systems. Retrograded Mediterranean Lows affect primarily the north-eastern part of Romania. Additionally, different mesoscale forcing mechanisms continuously generate convective cells and focus deep convection over a region for several hours, increasing thus the flash flood potential. ECMWF model analysis is used to investigate dynamical forcing and a mesoscale numerical simulation using the ALADIN model is carried out to investigate the mechanism responsible for convection development. Data from conventional weather stations, as well as radar and satellite imagery are used for investigating the role played by different modes of convective system organization in flash flood generation. The aim of this paper is to identify the different mesoscale and synoptic scale processes leading to continuous regeneration of convection in the same area, that leads contributes to heavy rain accumulation in a short period of time in north-eastern part of Romania.

**Key words**: severe weather event, flash floods, damages



## 1. Introduction

Heavy precipitation events in the Romanian territory can be attributed either to convective or non-convective processes, or to a combination of them. Large precipitation amounts can accumulate over several day-long periods when one or several frontal perturbations associated with Mediterranean cyclones are slowed down and enhanced by the Carpathian Mountains. These situations are very well known and documented in the specialized literature [1,5,8]. Alternatively, when a Mesoscale Convective System stays over the same area for several hours, significant rainfall totals can be recorded in less than a day. These high rainfall totals corroborated with short time periods they occur in, are likely to cause severe flash floods. The ones produced by mesoscale convective systems are distinguished from floods caused by synoptic-scale cyclones because flash floods tend to evolve on the same time and spatial scale as intense precipitation, leading to a short warning and response time [6]. Forecasting severe convection and flash flooding can be quite a challenge because flash floods are associated with different storm types and, additionally, depend on storm location and movement within the hydrological basin.

## 2. Data and Methodology

This study evaluates a particular extreme case of long-lived quasi-stationary convective systems associated with a retrograde Mediterranean cyclone over north-eastern Romania. Rainfall in 24 hours exceeded 150 mm and caused devastating flash floods in localities from the Suceava, Iasi, and Botosani counties, which result in human fatalities and important property damage. Herein we aim, first, to identify synoptic and mesoscale processes leading to deep convection and heavy rain development and, secondly, to find out the mesoscale factors that play a part in making mesoscale convective systems stationary. The quasi-stationary behavior of convective cells can be explained using the Chappel [2] conceptual scheme wherein convective cells are forced to repeatedly trigger over a certain area and are generally transported downstream by the mean tropospheric flow. If new convective cells can regenerate at a rate compensating the advective speed of older cells, the quasi-stationary of mesoscale convective system occurs. Diagnosing deep moist convection producing rain, on the other side, includes an evaluation of basic processes and their possible contribution and interactions (ingredients-based methodology) [6]. These processes go from synoptic scale, which has to produce the favorable environment, to mesoscale, which provides the lifting mechanisms for low-level parcels. A broad series of processes ranging from synoptic scale (areas of upward motion associated with troughs or upper level jets) to mesoscale (fronts, convergent lines, sea breeze fronts, upslope winds) and the scale of convection itself (gust fronts) can create that lift. Synoptic scale and mesoscale processes are evaluated using numerical model parameters from ECMWF (European Centre for Medium Range Weather Forecasts) model and ALADIN (Aire Limitee Adaptation dynamique Development InterNational) model data, Doppler radar products, high-resolution visible satellite imagery and conventional weather station data.

Since 2002, an operational network of five WSR-98 D (Weather Surveillance Radar) and two EEC-DWSR-2500C Doppler radars has been operational in Romania (fig.1).

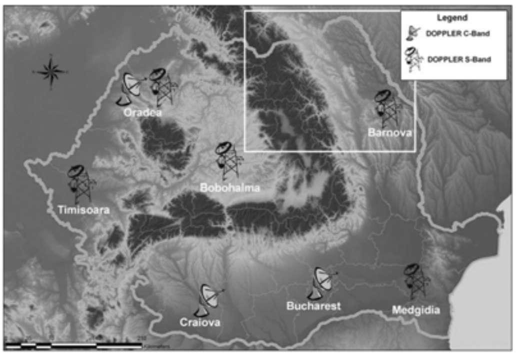


**Fig.1.** The Romanian National Radar Network integrates: five WSR-98 D S-band, 2 EEC-DWSR-2500C type and one Gematronik-METEOR 500C type). The flash flood area line marked with a white rectangle

This radar network system includes several algorithms using Doppler radar base data (reflectivity (dBZ) and velocity (m $s^{-1}$) as inputs to carry out a meteorological and hydrological analysis. The WSR-98 D is an important tool in detecting and forecasting severe storms, tornadoes, flash floods and other phenomena than those directly associated with severe storms (convergence lines, land/sea breeze fronts, gust fronts). The convective scale processes are identified using radar conceptual models.

## 3. Analysis of the atmospheric conditions

The surface analysis carried out on 24 July 2008 at 12:00 UTC detected the Mediterranean low-related fronts, with values of 1005 hPa across Romania, while North Europe was affected by the North European Anticyclone with values reaching 1025 hPa at its center (fig.2).

There was intense cyclonic activity on 24 July 2005. The ECMWF model caught the cyclone in its deepening phase, nucleus located in south-western Romania, as it can be noticed in the 500-hPa and 850-hPa geopotential and temperature fields (Fig.2). Over the analyzed 24-hour interval, the cyclone slightly evolved to the filling up phase, geopotential in the center increasing by 4 damgp, while its axis tilted slightly to the west.

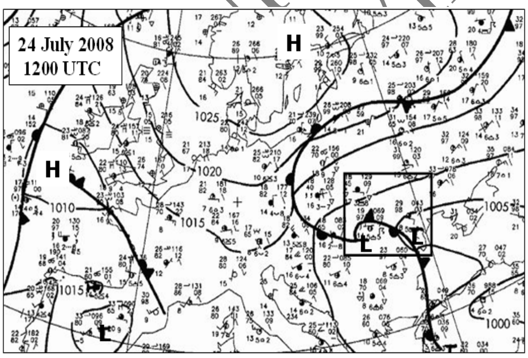


**Fig. 2.** Map of surface pressure field analysis and frontal analysis for 24 July 2008, 12:00 UTC, across Europe. The isobars are represented by lines; "H" indicates the North European anticyclone and "L" the cyclone. The fronts are represented by conventional symbols. Our country is under the influence of a Mediterranean cyclone (noted by "L" in the right part of the figure). The Romanian territory is roughly represented by the square

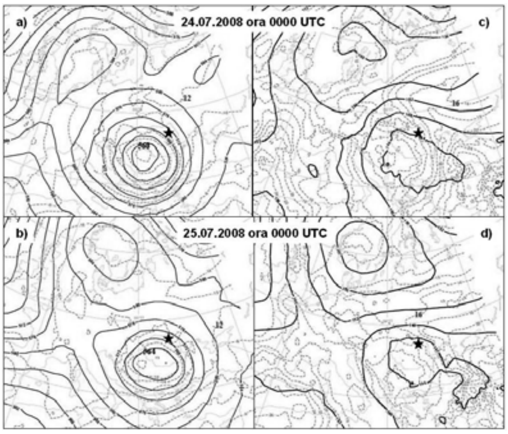


**Fig. 3.** Evolution of the 500-hPa and 850-hPa geopotential and temperature fields from the ECMWF model on 24-25 July 2008, 0000 UTC. Flooded area is marked by a blue star.

This slow activity led to a strong advection of warm air in eastern Romania, as it can be noticed in the 850-hPa Temperature field and in the relative field (500-1000) from the ALADIN model (fig.4a). Spatial distribution of CAPE from ALADIN model analysis at 15 UTC (fig.4b) showed values from 1000 and 4000 J $kg^{-1}$ over the north eastern part of the country with greater values in the low warm sector.

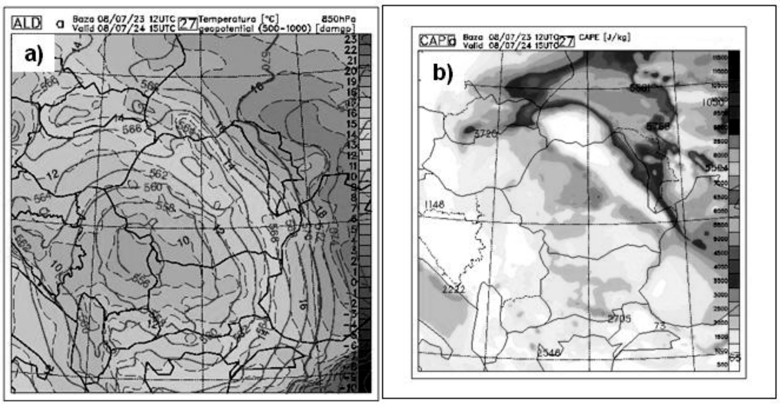


**Fig. 4.** a) 850-hPa Temperature and relative isohypses (500-1000) from the ALADIN model on 24 July 2008, 15.00 UTC; b) Spatial distribution of the CAPE index on 24 July 2008, 15.00 UTC, ALADIN model.

The mass of warm advected air from the Black Sea can also be noticed in the RGB satellite image (fig.5). The composite satellite image is obtained by water vapors and infrared channel differences. The infrared channel is used in determining the temperature of satellite-observed surface. For this reason, the RGB is useful for observing the air mass type. The front-related clouds from the frontal analysis (fig.2) can also be noticed in the satellite images from fig.5 and fig.6.

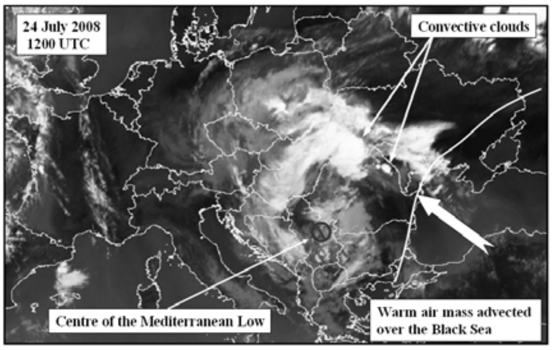


**Fig. 5.** The 24 July 2008 12:00 UTC composite satellite image. See the North Europe cold air masses and the South Europe warm air mass. It can be noticed the activity of the Mediterranean cyclone over Romania, which contributes to the advection of warm moist air mass from the Black Sea to eastern Romania.

The ALADIN model shows very high values of CAPE (>3000 J/kg), associated to the warm sector of the cyclone, which are due to the significant low-level moisture amounts transported from the Black Sea.

On 25 July 2008, the cyclone center was still in south-western Romania (fig.6). This stationarity of the cyclone, associated with a stationarity of the thermal discontinuity area on low levels in the warm sector of the low, made the convective developments appear and continuously move SW-NE (mean wind direction) (fig.6), across the same area over a time period up to 48 hours long.

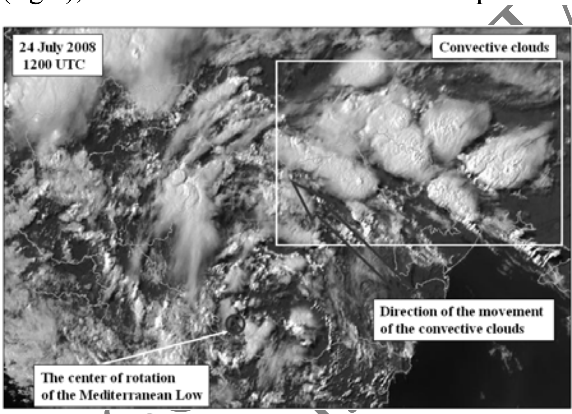


**Fig. 6.** The 25 July 2008 15:00 UTC weather satellite image. Cloud-covered areas are white, dry areas are black. The Mediterranean cyclone – still active over Romania, can be noticed, its center in the south-western part of the country. In north-east Romania and the Republic of Moldova convective cloud activity with great vertical development can be noticed following the red arrow.

The weather conditions wherein this convective system developed are sketched in Fig.6. This mesoscale system developed within a region of strong baroclinicity north-east of an intense cyclone of Mediterranean origin. Convection was initiated over an area of discontinuity on low levels within an extended warm sector of the surface low. The vertical wind profile shows a roughly parallel wind direction across the whole tropospheric column. The atmospheric models as well as radar data point out a low-level jet transporting warm moist air from the Black Sea area to north-east Romania. An analysis of the atmospheric conditions revealed the presence of basic physical processes required by convection development: conditionally unstable atmosphere, moisture on low-levels, forcing on synoptic scale and mesoscale forcing mechanisms related to low-level convergence. The quasi-stationarity of the cyclone had its contribution to the basic processes that lead to convection development occurring simultaneously in the same area. The quasi-stationarity of the mesoscale convective system was caused by that of the cyclone and the high precipitation accumulations in north Moldova were brought about by the way the mesoscale convective system's cells moved.

## 4. Evolution of the convective system obtained from radar data

The mesoscale convective system was observed by the Barnova (Iasi County) S-band WSR-98 D radar. Convective developments affected the same north-east Moldavia area in the night of 23/24 July and in the afternoon and night of 24 July. The system's SE-NW direction maintained throughout this interval and convective cells moved on like a cell "*train*" over north-eastern Romania .

On 24-25 July 2008, the system's convective cells moved on the average wind along the system. The vertical wind profile obtained from radar data (fig.) shows a parallelism between tropospheric wind direction and the linear system. The presence of low-level jet at wind speeds about the average wind led to the speed at which new convective cells developed in the system being equal to the dissipating speed of those getting out of the system on mean wind. Thus, the system became stationary. Accumulated precipitation related to this stationary system, recorded by weather stations and rain-gauging posts on 24-25.07.2008 06 UTC topped 150 mm over 24 hours in Suceava, Iaşi and Botoşani counties, as shown in fig.8.

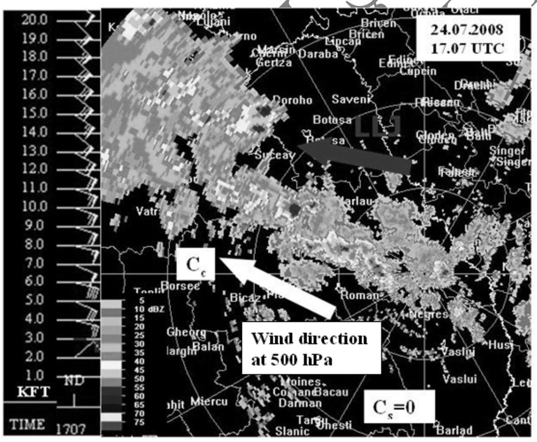


**Fig. 7.** 24 July 2008 quasi-stationary mesoscale convective system observed by the Barnova S-band radar at 17.07 UTC. Propagation component of system cells ($C_c$) equal to 500hPa wind and Low Level Jet (LLJ) equal to 500hPa wind are represented in the figure. System's propagation component ($C_s$) is equal to 0. Vertical Wind Profile obtained from VAD (velocity azimuth display – a radar product) is shown in the left.

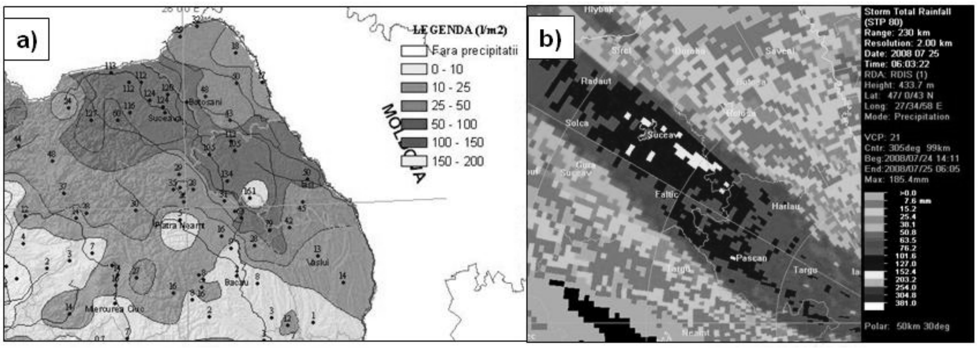


**Fig. 8.** a) Precipitation amounts related to the stationary convective system: accumulated over 24-25 July 2008 0600 UTC at weather stations and rain-gauging posts; b) accumulated between 24.07.2008 14.11 UTC and 25.07.2008 06.05 UTC, from radar data.

On 23-26 July, precipitation related to the quasi-stationary mesoscale convective systems made accumulation levels reach high values. These large amounts fell over a hilly and mountainous area from northern Romania, causing flash floods.

## 5. Conclusions

A description of a deep moist convective event which produced flash flood over north-eastern Romania has been presented. The meteorological synoptic-scale and mesoscale context were analyzed and the evolution in which the mesoscale convective system was embedded was described. At the synoptic scale, the meteorological pattern for this case was characterized by a deep cyclonic circulation generating a strong south-easterly flow over the north-eastern part of the country. This cyclone gets a retrograde movement over the Black Sea and thus contributes to the increased moisture content of the forming convective. The surface pattern revealed a low pressure area situated over the Black Sea thus the eastern part of Romania was situated in an area with strong warm advection. These low-level synoptic patterns induced an intense south-easterly low-level jet which favored a strong low level moisture transport and significant conditional convective instability over the flooded area. Convection was initiated over an area of discontinuity on low levels within an extended warm sector of the surface low. For this torrential precipitation event the basic processes for a flash-flood producing system, as pointed out by Doswell [6], were present: a conditionally unstable atmosphere and moist low levels in the presence of large scale forcing and mesoscale lifting mechanism provided by low level convergence. Even though synoptic-scale processes provided necessary conditions for the convective activity, factors at mesoscale and storm scale contributed to continuously focus the activity over the same region. The movement of the mesoscale convective system was modulated by the low level jet. The south-east low level jet oriented approximately parallel with the discontinuity line, determined the development of convective with a rate equal with the dissipating speed of those getting out of the system on mean wind in the rear part of system, and the new cells repeated the movement along the convergence line. This pattern was in accord with "train" effect movement for mesoscale convective system conceptual model described by Schumacher and Johnson [9]. This type of organization of the convective system has created high rainfall accumulation in a short period of time (150 mm over 24 hours in Suceava, Iasi and Botosani counties), but the magnitude and orientation of the hydrological basins in this area was the factor that marked the differences between a torrential precipitation rainfall and a flash flood event.

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