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MESOCYCLONES IN ROMANIA – CHARACTERISTICS AND ENVIRONMENTS

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1. Introduction

The Weather Service in Romania recently acquired through the SIMIN (National Integrated Meteorological System) Project, eight Doppler radars, five of which are WSR-98Ds, a clone version of the WSR-88D used by the U.S. National Weather Service (Fig. 1). Upon installation, the Romanian forecasters faced challenging issues. One was interpreting Doppler radar data because convective storms in Romania have never before been observed with Doppler radar. Second, there was a general belief among the meteorologists that supercells and tornadoes do not occur in Romania. After five years of observations, several attributes of severe storms have been documented. Answers to questions such as what is the prevalent storm type that causes severe weather and where severe weather happens more often are beginning to emerge. Finally, rotating storms (mesocyclones) do occur in Romania and some have produced tornadoes.

The first tornado observed in Romania using Doppler radar was at Facaeni (Lemon et al. 2003), after which the tornado threat in Romania became recognized. That this storm formed in Romania from a supercell meant that supercell storms become "targets" for nowcasting severe weather. Romanian forecasters are challenged to recognize environmental mesoscale factors that favor the onset of supercellular thunderstorms, mainly in southeastern Romania, where the environment tends to be more conducive to severe convection than in other parts of the country (Stan-Sion and Antonescu 2006). Deep moist convection is a result of three ingredients: lift, instability, and moisture (Johns and Doswell 1992). Thus, we consider that intense convection will occur provided that large convective available potential energy (CAPE) is present in the air column and provided that the typical negative area (CIN, or convective inhibition) below the level of free convection for surface air is somehow removed or reduced to a small value that can be overcome. Observations of storms whose buoyant updraft contains air originated in the boundary layer often shows that they are initiated along or near surface airstream boundaries, especially in the southeastern Romanian Plain. An airstream boundary is defined as a line of discontinuity or a narrow zone separating air having different meteorological properties (e.g., Cohen and Kreitzberg 1997; Markowski et al. 1998; Cohen and Schultz 2005). Mesoscale lift along such surface boundaries can decrease the convective inhibition, increase the convective available potential energy, and moisten the air column (e.g., Wilson and Schreiber 1986). Surface boundaries are also an important source for low-level shear that can favor or enhance the development of mesocyclonic storms. In this paper, the mesoscale patterns and the conceptual models of the features which favored development of surface boundaries connected with mesocyclones are analyzed.

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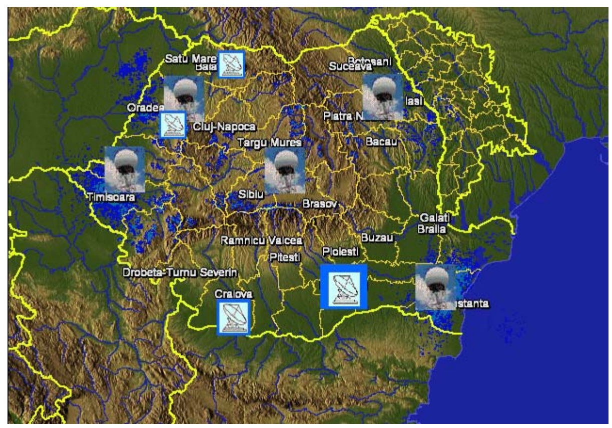

Fig. 1: The Romanian National Radar Network integrates: 5 WSR-98D S-band radars (a clone version of WSR-88D radar used in US NWS network) and 3 C-band radars (2 from EEC – DWSR-2500C type and 1 from Gematronik – METEOR 500C type).

2. Surface boundaries in southeastern Romania

Experience of forecasters in southern Romania have shown that three types of surface boundaries are present: synoptic, mesoscale, and convective boundaries (Stan-Sion and Soci, 2005). Synoptic boundaries consist of fronts (e.g., cold, warm, and stationary) and the interaction of the synoptic flow with orography. Fronts are generally well predicted by the models so we will not consider these in the present study. On the other hand, the interaction of the synoptic flow with the curved shape of the Carpathian Mountains results in a convergence zone between the eastward and westward circulations (Bordei-Ion, 1988), discussed further in section 2a. Mesoscale boundaries consist of drylines, discontinuity lines produced by differential heating due to cloud cover under anvils, convergence lines produced in the lee of a mountain chain, sea-breeze fronts, and mountain-breeze circulations. Examples of such circulations are presented in sections 2b and 2c. The last category, outflow boundaries, are the most difficult to predict as they are produced by the convection itself. The radar is the most appropriate tool to monitor the behavior of the convectively generated cold pool and its associated gust front. Predicting the initiation of convective storms along an outflow boundary before the onset of the parent storm is difficult, if not impossible. An example of convective initiation along an outflow boundary is presented in section 2d.

a. Back-building squall line conceptual model and the convergence zone in southern Romania

The Romanian topography is dominated by the S-shape of the Carpathian Mountains (Fig. 2). The fingerprint of this pattern on the low-level wind is the so-called Romanian Plain Convergence Zone that often forms in southern Romania.

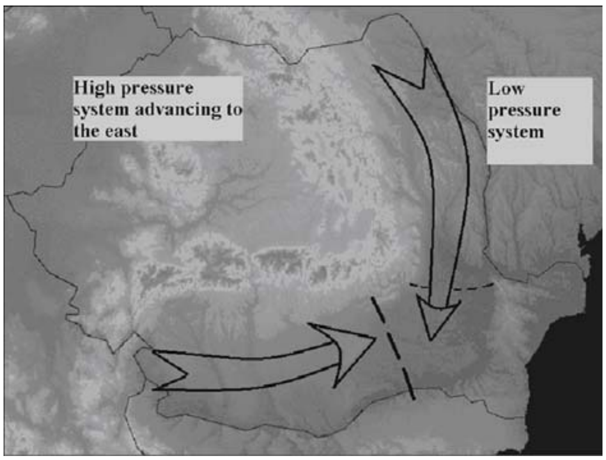

Fig. 2: The „Romanian Plain Convercence Zone": Arrows depict the pericarpathian flows that converge in the middle of the Romanian Plain when a western high pressure system approaches the Carpathian Curvature. The solid dashed line represents the region of convergence where convection is often initiated. The thin dashed line, zonally oriented, represents secondary „cold fronts" that can form.

This convergence zone is produced by the pericarpathic flow when a high-pressure system approaches from the west. The flow splits into branches (one with northern direction of the flow and the other one with south-western flow, Fig.2) around the obstacle and the convergence region of these two flows can shift to the east or to the west, depending on which branch is more intense. This convergence zone is similar to other mesoscale convergence zones produced by flow around complex topography like the Puget Sound Convergence Zone (e.g., Mass and Dempsey 1985) and the Snake River Convergence Zone (e.g., Andretta and Hazen 1998)

The Romanian Plain Convergence Zone (RPCZ) interacts, in appropriate synoptic conditions, with a southerly low-level jet or can intersect with other boundaries; in these conditions, severe convection is initiated near the RPCZ. This is the case of a back-building squall line with zonal orientation that often forms on the southern slopes of the Meridional Carpathian Mountains. The first convective cells form on a zonally oriented, secondary, strong, cold front, perpendicular to a northerly flow on the eastward branch of the pericarpathic flow over Moldavia (fine dashed line in Fig. 2).

If there is a southly warm, moist, low-level jet (shown by the red arrow in Fig. 3a), intensified also by the daytime mountain breeze on a sunny day, then the propagation of the convective system, or the direction in which the new cells will form in respect to the general westerly flow, will be oriented toward the west. This is termed a backward-propagating or backbuilding convective system (e.g., Bader et al. 1995, pp. 418–421; Schumacher and Johnson 2005).

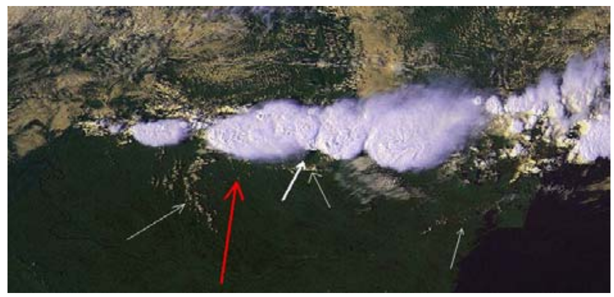

Fig. 3 a: NOAA satellite image from 21th of August 1991, 13:21 UTC. The image shows a back-building squall-line zonally oriented. Arrows indicate the shallow cumulus produced by (from left to right) the convergence zone, the differential heating by the anvil shadow, the outlow boundary and the Black Sea breeze. (Courtesy Martin Setvak)

This was the case that happened on 21 August 1999. The satellite image (Fig. 3a), shows the squall line in its mature stage and also surface boundaries that are in place in the same time. The convective cells developed from the east to the west although the dominant upper flow was in the opposite direction.

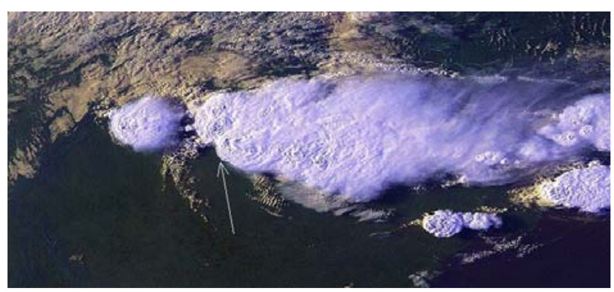

Fig. 3 b: NOAA satellite image from 21th of August 1991, 15:12 UTC. Arrow indicates severe convection initiation in the intersection region of two previous boundaries. (Courtesy: Martin Setvak)

The outflow boundary of the cell situated in the middle of the line, was intensified by the thermal boundary produced by the shadow of a stationary anvil. The sun was situated to the west with respect to the cell, so the anvil shadow has superposed with the outflow boundary (the intense white arrow in Figure 3a). The region of intersection of these two types of surface boundaries, at the northern edge of the convergence line, became the place where a strong convective cell developed later (Fig. 3b).

At that time, no Doppler capabilities were installed. Hail 10-cm in diameter and 120 mm of rain in one hour were reported in the town of Curtea de Arges. Also, strong winds destroyed the roofs of many houses, and the electricity poles were seriously damaged, but no tornado was reported.

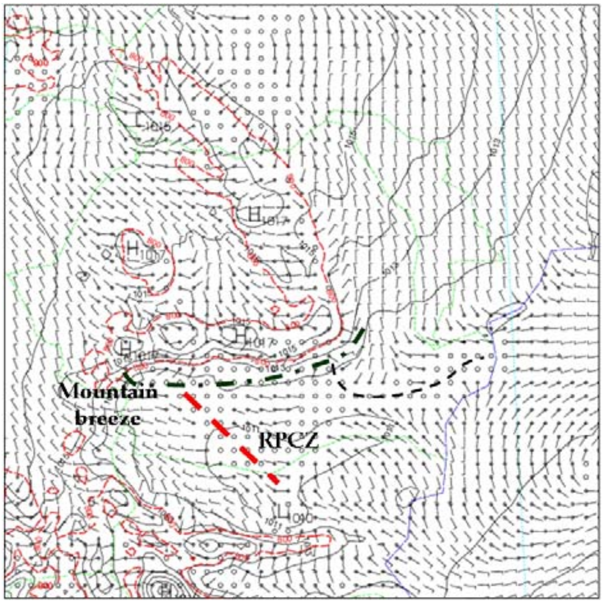

Fig. 4a: ALADIN model analysis for 21 August 1991, 09 UTC, MSLP and wind. Red line depicts 800 m orography. Local flows are shown.

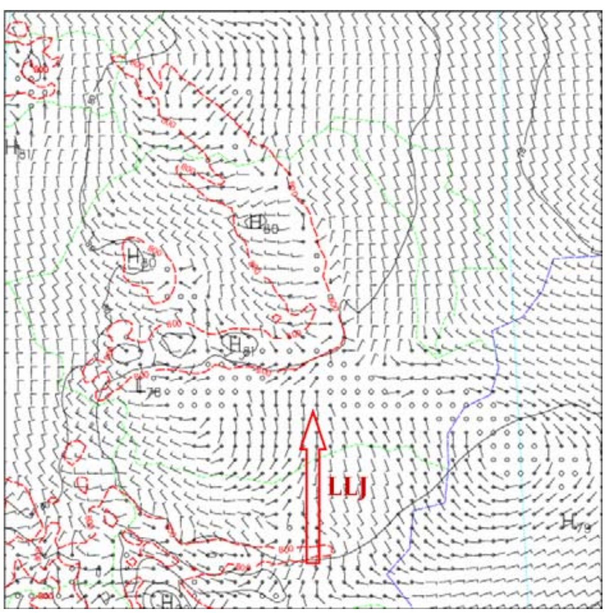

Figure 4 b. ALADIN model analysis for 21 August 1991, 09 UTC, heights and wind at 925 hPa. Red line depicts 800 m orography. Southerly flow is shown.

The ALADIN model could depict the onset of the mountain breeze, the RPCZ and the secondary cold front (thin dashed line in Fig 4a). Also, the model depicts low level flow in the wind field (Fig.4b).

Another factor that can enhance this southerly low level jet (LLJ) during the general zonal circulation in middle and upper levels, is the negative anomaly in pressure field (depicted with the – sign in Fig. 5) and the collocated positive thermal anomaly (unshown) generated by the flow over a mountain obstacle (Bluestein 1993, p. 39-41). Also the CAPE field provided by ALADIN indicated high values up to 5500 J/Kg.

b. Surface-boundary interactions with sea and mountain breeze

In the case of a prevailing of the northern branch in Figure 5, the convergence line can interact with a boundary produced by the sea breeze (situated east of the boundary) or with a LLJ associated with the mountain breeze (weast of the boundary). The points of this interaction, (Fig. 5) can be the place of initiation of severe convection.

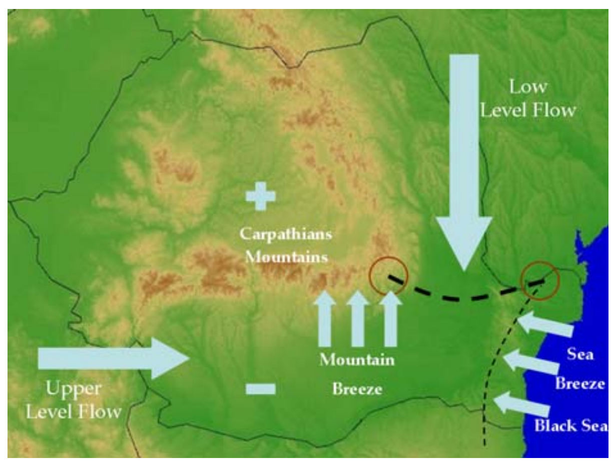

Fig. 5: The conceptual model of storm initiation in Southeastern Romania when the nordic branch of the percarpathian low level circulation is prevailing (big arrow). The middle and upper flow is zonal and induce two major pressure anomalies in low levels: a positive one (the + sign inside the Carpathian Arc) and a negative one (the – sign in the southwest of Romania). Circles represents places where severe convection is favoured due to local differential heating mechanisms like mountain and ses breezes.

Such a situation happened during the afternoon of 17 August 2005 when the surface boundary ahead of a northerly low level flow (synoptic boundary) intersected the intense southerly LLJ (CAPE values of 4500 J/Kg) to the west, and also a new boundary produced by a convective outflow. The sea breeze was also active, but there the instability was not as high as in the western air mass (Fig.6).

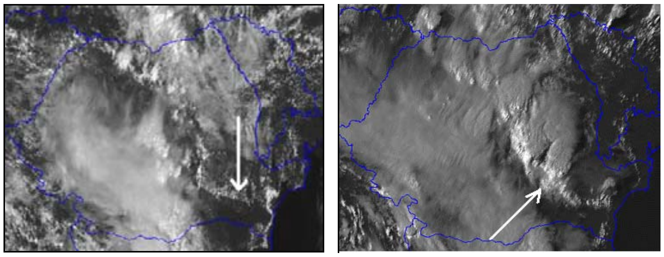

Fig. 6: Left: METEOSAT7 satellite VIS image, 17 August 2005, 1200 UTC. The white arrow indicates the surface boundary of the pericarpathic northern flow. Right: METEOSAT7 satellite VIS image, 17th of August 2005, 1445 UTC. The white arrow points toward the overshooting of an intense updraft that developed at the intersection with an intense LLJ and outflow boundary.

The new boundary (Fig. 7) produced by convective outflow intersected the synoptic boundary and a strong updraft developed; an overshooting could be seen on the satellite VIS image. The WSR-98D S-band radar installed at Medgidia (southeast Romania) detected also the outflow boundary (Fig. 7, lower part).

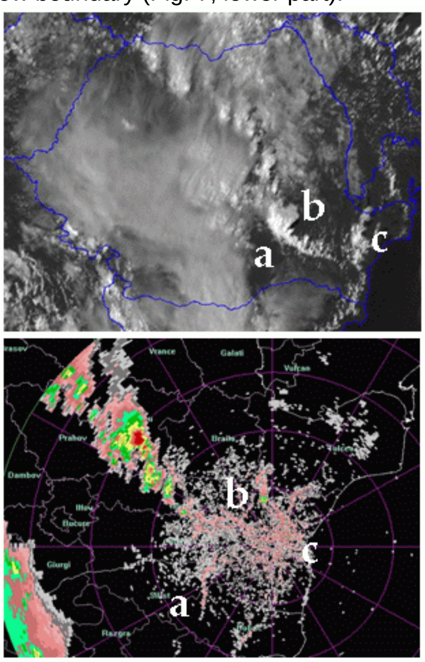

Fig. 7 Upper part : Meteosat VIS image, 17 August 2005, 1507 UTC. Lower part: WSR-98D Medgidia, reflectivity, first tilt, same time. (a): outflow boundary, (b): synoptic boundary, (c): sea breeze

The intersection of these boundaries were near the place where a strong supercell developed. A persistent mesocyclone was identified on radial velocities (Fig. 8). Some villages in Buzau county, affected by that supercell, reported big hail, strong winds and a total amount of 75 mm of rain in one hour. A funnel cloud was also reported.

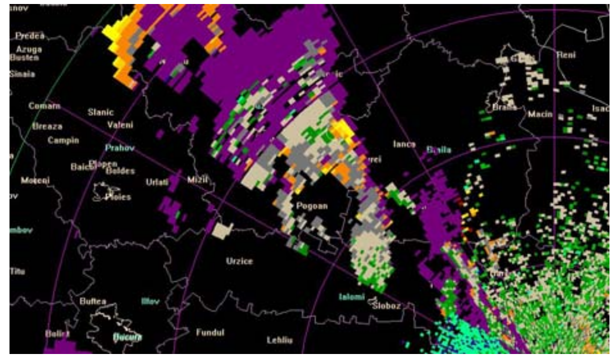

Fig. 8: WSR-98D radar in Medgidia, radial velocities, first tilt, 17 August 2005, 1613 UTC.

The „mirror" situation, with convective development at the oposite side of the boundary, happens when the big values of CAPE encourage the convective development at the eastward point of intersection with the sea breeze front (Fig. 9a).

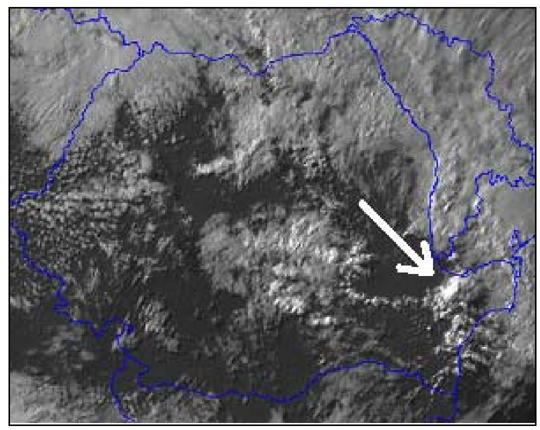

Fig. 9a: Meteosat7 satellite VIS image, 6th July 2005, 1445 UTC. The arrow points toward the intersection between two surface boundaries where severe convection developed and a tornado was reported.

This was the case during the afternoon of the 6 July 2005, where a tornado was reported in the village of Topolog and a forest nearby was damaged. The Doppler radar reflectivity field showed all the severe structures associated with a supercell; also the radial velocities showed the rotational structure in the velocity field (Fig. 9b).

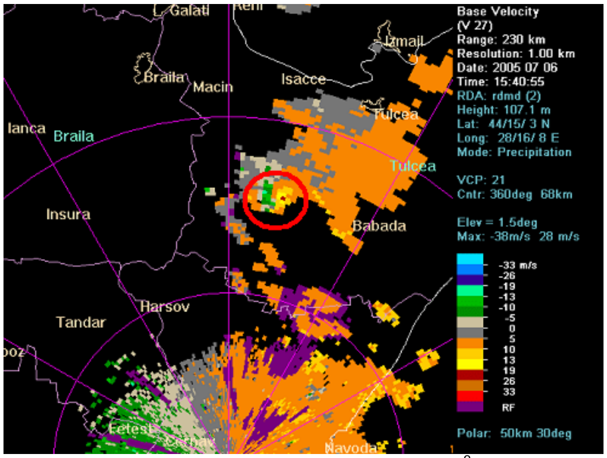

Fig. 9b: Radar image of radial velocities at 1.5° elevation, on the 6 July 2005, 1540 UTC. WSR-98D, Medgidia site. The red circle indicates the tornadic mesocyclone.

c. Meridional squall lines along convergence lines in Southern Romania

If the convergence zone is more active and the LLJ is well channeled and is oriented along the convergence line, than the initiation of severe convection can take place directly on the line of wind convergence. On 23 July 2004, the biggest greenhouse in Europe on natural soil, from Popesti-Leordeni near Bucharest, was destroyed by severe hail. The convergence line in this case was situated in the center of the Romanian Plain. The satellite image (unpresented here) shows the line of cumulus that formed along the convergence line as early as 9 UTC. The squall line developed on this convergence line four hours later. The southern cell from this line evolved into a supercell, displaying a hook echo oriented toward the LLJ and the associated mesocyclone. The radar vertical cross-section also indicated other severe radar structures like „overhang" and „bounded weak echo region" associated to the conceptual model of a supercell, as described in Lemon and Doswell (1979). The CAPE values were as high as 4000 J/Kg in the region of the convergence line. The

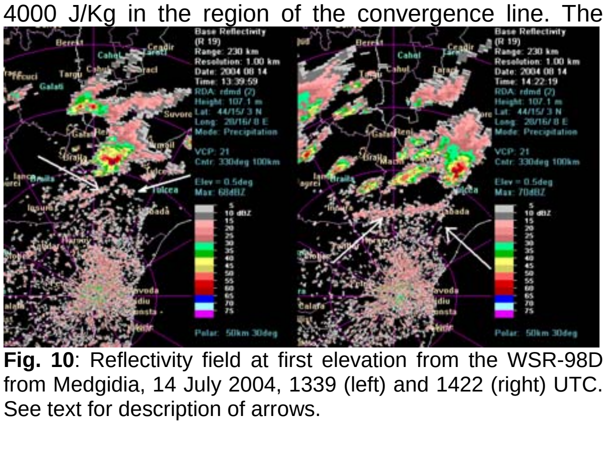
Fig. 10: Reflectivity field at first elevation from the WSR-98D from Medgidia, 14 July 2004, 1339 (left) and 1422 (right) UTC. See text for description of arrows.

movement of the squall line was slow but retrograde with respect to the upper level flow, the propagating component being oriented toward the southwest where the main axis of the moist and humid air mass was positioned.

d. Convective boundaries and the evolution of convective storms

Outflow boundaries separate evaporatively cooled air produced by the convective-storm downdrafts and ambient, warm air. The location of the cold pool can be determined from the radar reflectivity field, satellite images, or surface data. The challenge for a forecaster is when such a structure is not well developed or not seen on radar imagery, but when it can provide the cell with more vorticity or vertical velocity. This is the case of a supercell on 14 August 2004, in which two enhancing episodes of its mesocyclone occurred. The first one (Fig. 10, left panel) arises when the supercell crosses the remnants of a convective cold pool from a previous convective cell. The left arrow indicates the rear flank downdraft (RFD) of the supercell, which is also a convective outflow boundary, and the right arrow indicates the outflow from a convective cell that has passed previously over that location. The mesocyclone in radial velocity, unshown here, had an enhancement right at the moment when the hook echo passed over this boundary. Later, a new enhancement of the mesocyclone was observed in the radial velocity field, when the supercell intercepts the boundary associated with the sea breeze, indicated by the arrow (Fig.10, right panel). This was a tornadic high-precipitation supercell that produced a flash flood. The intensity of the strong cold pool left by the mass of precipitation can be inferred from the more intense RFD in the right panel. This storm produced two fatalities due to tornado and flood in the city of Tulcea.

3. Conclusion

Supercells are associated with severe weather in Romania. In the last five years of Doppler radar observations, the frequency of mesocyclones that formed in Romania is higher in the southeastern part of the country. An exceptional year was 2005 when 13 tornadoes were reported (Fig. 11).

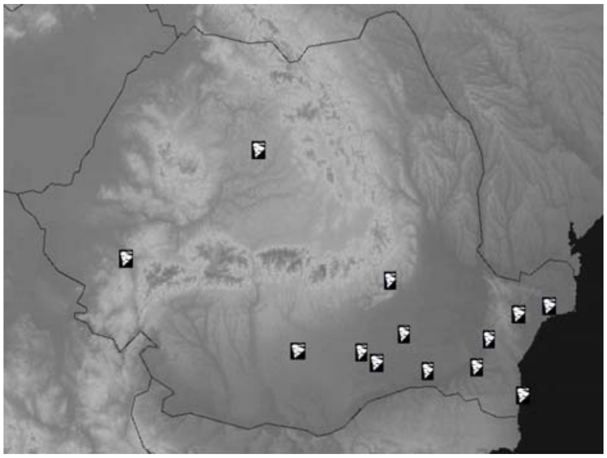

Fig. 11: Distributions of tornadic events during 2005 in Romania.

Three different types of surface boundaries that precede some severe convective episodes in southeastern Romania are presented. The boundaries are related to local topographic circulations and the general synoptic flow; they include: convergence lines induced by the S shape of the Carpathian Mountains in south Romania, the Black Sea breeze convergence lines, and boundaries induced by convection like outflow boundaries and differential heating boundaries. The conceptual models suggested in the paper,emphasized with some examples, try to explain the low level special conditions of supercells that forms in the vicinity of boundaries.

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