THE IMPACT OF SEVERE CONVECTIVE PHENOMENA IN SĂLAJ AND MARAMUREŞ COUNTIES. CASE STUDY: SUPERCELL ON MAY 28th 2019

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ABSTRACT. The impact of severe convective phenomena in Sălaj and Maramureş counties. Case study: Supercell on May 28th 2019.
The main purpose of the study is to analyze the conditions and impact of severe weather phenomena in Sălaj and Maramureș counties. A supercell storm that crossed a significant part of the mentioned area in the 28th May 2019's afternoon, also affecting Zalău and Baia Mare was chosen as a case study through its impact and severe threats that occurred, leaving many damages over the area. The analyzed phenomena are convective, generated by Cumulonimbus clouds with a considerable vertical extent. Synoptic and mesoscale conditions were determined using the specific methods of investigation (charts of sea level pressure, geopotential height, temperature and humidity, atmospheric soundings, different stability indices, vertical wind shear, infrared and visible satellite images and radar images of convective storms). The main findings are: synoptic conditions were determined by low values of atmospheric pressure at the surface and by the atmospheric depressions, while in the middle troposphere, an atmospheric trough was present; mesoscale conditions presented: elevated values of Convective Available Potential Energy, negative values of Lifted Index, and strong wind shear in the 0-3 km layer.

Keywords: supercell, severe weather phenomena, hail, Sălaj, Maramureș.

1. INTRODUCTION

On May 28th 2019, a series of convective weather systems affected the western and northwestern part of Romania. Among them, the most severe was the one initiated in the Apuseni Mountains, south-east of Vlădeasa Mountain (Cluj County) crossing Sălaj and Maramureș counties (fig. 1), on a north-north-east trajectory.

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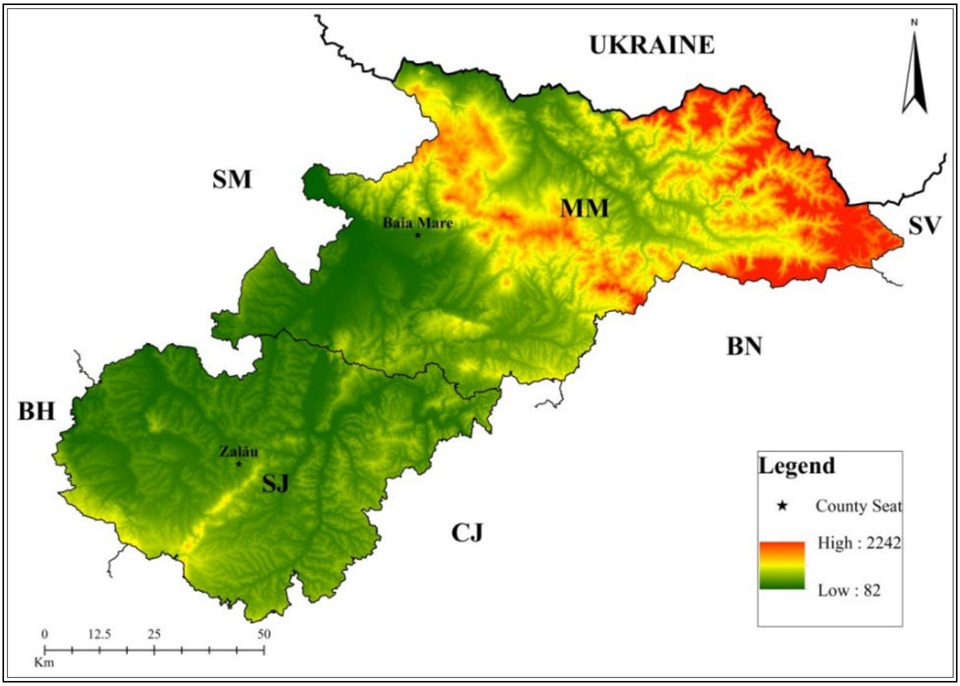

Fig. 1. Sălaj and Maramureş Counties.

The convective system rapidly developed into a supercell, displaying features of strong rotation and vertical wind shear. The synoptic conditions consisted in an upper-level trough and a warm tropical air advection, favorable of high convective instability as parameters and stability indices predicted. The presence of a strong wind shear of 17-20 m/s in the lower and middle troposphere, played a high role in the development of rotational structures and intense phenomena, high values of Convective Available Potential Energy (CAPE).

It is well known that climate change influences severe phenomena that have a higher frequency and an increasingly high potential. Thus, extreme weather events pose an increasing threat as climate changes. The definition and classification of convective storms have become more complex and, in many ways, more troublesome than ever before (Doswell & Burgess, 1993), being severe if producing wind speeds above a damaging threshold, hail exceeding a certain diameter (Seeley & Romps, 2015).

In the northwestern Romania, such super cellular convective systems are increasing in frequency, though their frequency is very rare (Buglea & Cigher, 2021), a good example being the situation of 19 June 2016. According to the studies carried out by the National Meteorological Administration, on 19 June 2016, in the northwestern area of Romania, due to atmospheric instability well-developed convective systems appeared with cloud heights up to 15 kilometers, which generated torrential rains, large hail, frequent lightnings and intense wind gusts, which resulted in significant material damage. However, it can be highlighted that, certain thunderstorms may develop into a nearly steady-state structure that persists for several hours (Klemp, 2003), this being well defined in the evolution of the 19 June 2016 and 28 May 2019 convective systems.

2. METHODOLOGY

The study involved methods of analysis and observation to examine the processes that generated the phenomena on May 28th 2019 in the Sălaj and Maramureș Counties. Synoptic and mesoscale conditions were analyzed using sea level pressure (SLP), geopotential, temperature, wind speed and direction, and humidity weather charts for 1000, 925, 850, 700 and 500 hPa based on reanalyze maps provided by https://meteologix.com/ro/reanalysis and https://www.wetter3.de/Archiv/. Air circulation was computed using *HYSPLIT Trajectories* facilities at https://www.ready.noaa.gov/HYSPLIT.php (Stein at al., 2015, Rolph et al., 2017). Only for mesoscale analyze, atmospheric parameters and stability indices (Entire Atmosphere Precipitable Water – EAPW, CAPE, Convective Inhibition – CIN, Lifted Index – LI, vertical wind shear), atmospheric soundings, radar images of reflectivity and precipitations (One Hour Precipitation – OHP, Three Hour Precipitation – THP), infrared (IR) and visible (VIS) satellite images provided by http://weather.uwyo.edu/upperair/sounding.html, http://eumetrain.org/ePort_Map Viewer/index.html, and https://www.estofex.org/modelmaps/browse_gfs.php, for the 28th of May 2019 were used. Also, satellite images (HD and Cloud Tops Alert) from https://meteologix.com/ro/satellite/romania/satellite-hd-5min/20230831111 0z.html, volution of lightning detection (https://www.blitzortung.org/en/his torical_maps.php), and meteorological data from Zalău and Baia Mare weather stations provided by National Meteorological Administration (ANM). In order to highlight certain important features such as the studied area and storm's path, cartographic maps were processed in the Geographic Information System (GIS) program and the European Severe Storms Laboratory's (ESSL) reports were accounted as reliable source to confirm the occurred severe phenomena in the area (https://eswd.eu/).

3. RESULTS AND DISCUSIONS

On May 28th 2019, 00 UTC, Romania was on the descendent slope of a long-wave upper-tropospheric trough, therefore associated with a Rossby wave, whose axis was centered over the central Europe (fig. 2, left). The downstream side of the tropospheric wave was characterized by a strong warm air advection with a great influence over the evolution of the meteorologic phenomena during the analyzed period. At the contact of polar maritime air mass, situated in the northwest part of Europe and tropical continental air mass, from the southeast part of the continent, a strong jet stream had developed, represented on the wind speed chart of 300 hPa (fig. 2, right).

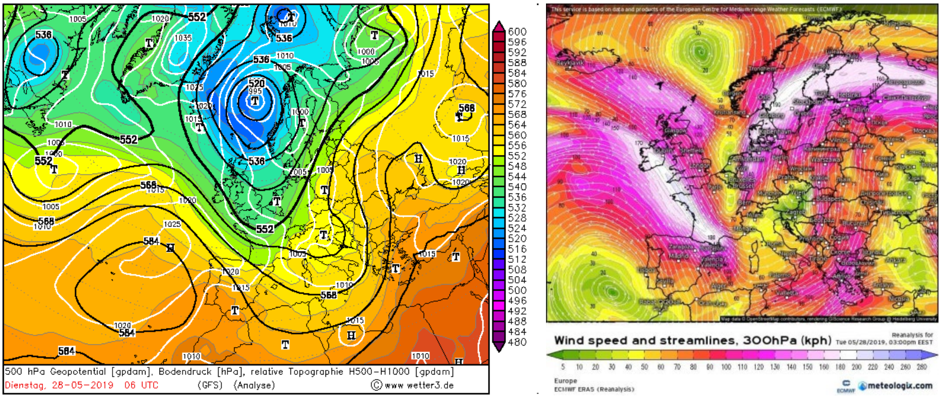

Fig. 2. Geopotential height at 500 hPa, Thickness 500-1000 hPa (gpdam), and Sea Level Pressure (hPa) on 28th May 2019, 06 UTC (left), Wind speed at 300 hPa (kph) on 28th May 2019, 12 UTC (right)
Source: https://www.wetter3.de/Archiv/, https://met eologix.com/ro/reanalysis

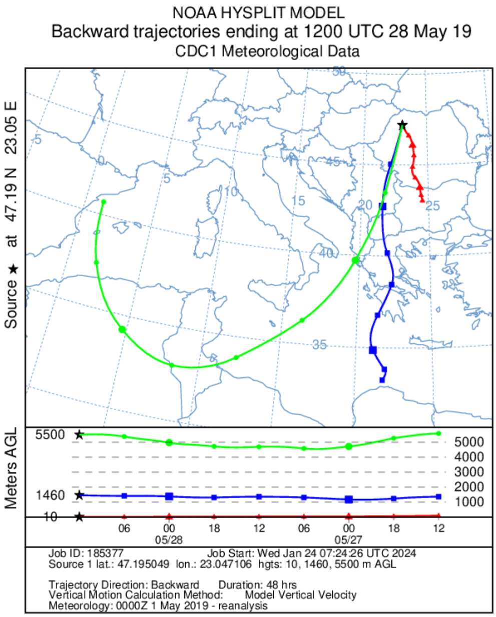

Fig. 3. The backward trajectory computed for air mass movement on 28.05.2019, 12 GMT. Source: https://www.ready.noaa.gov/ HYSPLIT_traj.php

The downstream side of the trough was characterized by a cyclonic curvature as well as a strong horizontal shear, driven by elevated thermobaric gradients, thus resulting in positive vorticity advection in the western Balkans as well as in the western and northwestern regions of Romania. The exit from the jet streak, associated with positive vorticity advection, determined the divergence of the wind in the upper troposphere, representing an important convective trigger for the study area. Surface mesoscale analysis helps to explain these different storm evolutions due to interaction among local circulations (Alberoni et al., 1996).

At the surface, a low-pressure system was moving to northeast, affecting central and eastern Europe, generating a warm and moist air advection in the lower and medium troposphere (fig. 3). All of these atmospheric conditions as well as the orographic features related to them were present within the proximity of a cold frontal passage over the Romania's territory.

The environmental conditions were favorable for the development of deep convection especially in the Sălaj county, reflected by the atmospheric instability indices: CAPE values of 2000 to 2800 J/Kg (fig. 4, left), associated to a wind shear of over 17 m/s in the 0-6 km layer, and the base ingredient relative humidity values of 60% to 70% near the surface, providing significant supply of moisture due to the circulation from the southwest (Tudose & Moldovan, 2005). The presence of moist layers at about 3000 m altitude, suggested by the relative humidity values of 80% to 90% at the geopotential level of 700 hPa, and high values of precipitable water of around 29-32 mm (fig. 4, right), favored the presence of strong updrafts, and the development of hailstones. This was a situation with a high potential for the occurrence of flash floods, thus torrential rains fell on extensive areas (Blaga, 2015).

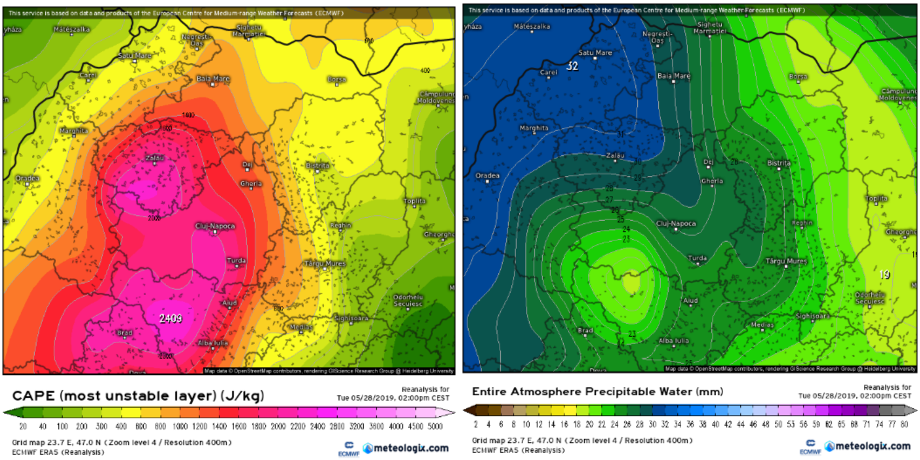

Fig. 4. CAPE (J/kg) (left), Entire Atmosphere Precipitable Water (mm) (right) on 28th May 2019, 12UTC
Source: https://meteologix.com/ro/reanalysis

The elements mentioned above led to the genesis of a cellular convective systems, such as the one that affected the cities of Zalău and Baia Mare during the afternoon of May 28th, 2019.

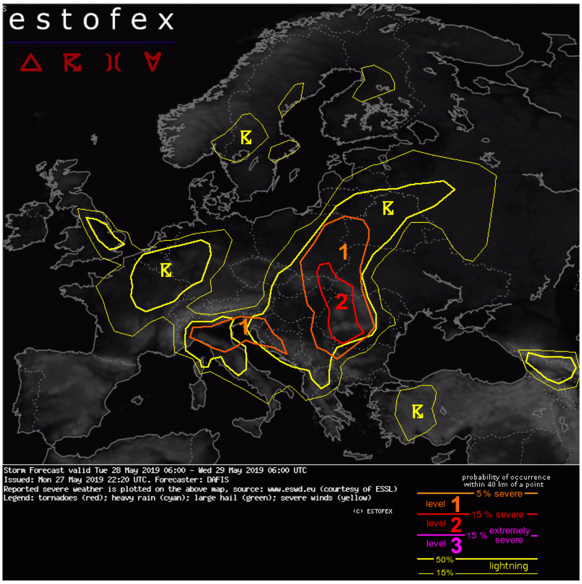

Fig. 5. Storm Forecast - ESTOFEX for 28th May 2019, 06 UTC - 29th May 2019, 06 UTC
Source: https://www.estofex.org/

European Storm Forecast Experiment (ESTOFEX), "an initiative of a team of European meteorologists, and students in meteorology" that publishes daily forecasts of the convective weather probability in Europe (www.estofex.org/), issued a warning of level 2 threat (fig. 5) for the southwest half part of Romania, northeastern part of Hungary, eastern part of Slovakia, southeastern part of Poland and southwestern part of Ukraine for large hail, severe wind gusts and excessive precipitation.

3.1. Supercell path – from genesis to dissipation

According to the satellite data from https://meteologix.com/ro, the supercell system formed in the Valea Drăganului-Ciucea area (Cluj County) around 10:50 UTC. Its direction was northward until entered in the area of Sălaj county, at about 11:30 UTC, when the direction changed to north-northeast (fig. 8, left). The convective system met the perfect environment for intensification, fact confirmed by the rapidly growing number of lightnings (fig. 6). Local people in the area of Pria, Cizer commune, confirmed that the cloud had a very dark base, with a slight rotation, which indicated the high potential of the severe phenomena and the possible supercell formation. The cloud system followed the configuration of the Meseş Mountains, finally reaching Zalău city around 12:00 UTC. At that moment the cloud was at its lowest top temperature: -60°C, underscoring its great vertical extent (fig. 6).

From public reports, the cloud system had a very dark base with a turquoise tint which was confirmed by pictures (fig.7, left), indicating a high risk of large hail. Only 5 minutes after the almost complete darkening of the sky, due to the high horizontal and vertical extent of the supercell, the "siege" began with heavy rain, frequent lightning, and strong wind gusts, indicators of the strong downdrafts and intense evaporation cooling process. After that, the hail begun, starting with small hailstones of about 1 cm, immediately followed by larger ones, which according to the ESSL's reports, reached 4 cm and even up to 6 cm in diameter, then continuing with smaller sizes but in significant quantities.

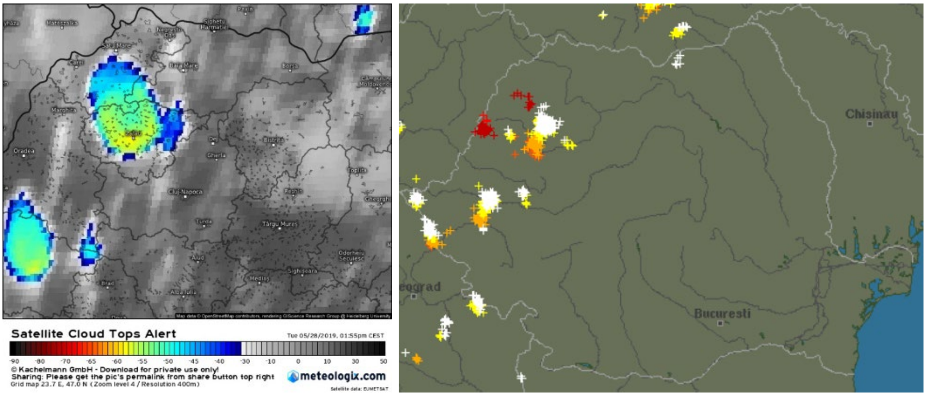

Fig. 6. Satellite Cloud Tops Alert on 28th May 2019, 11:55 UTC (left), Lightning Strikes on 28th May 2019, 11:50 UTC (right)
Source: https://meteologix.com/ro/satellite/237-e-470-n/top-alert-5min/20190528-1155z.html, https://www.blitzortung.org/en/historical_maps.php

Fig. 7. Cloud Base in Zalău city (left) and Red Warning Alert issued by ANM (right), on 28th May 2019, 12:00 UTC
Source: photo: Mihai Crișan, Red Warning Alert: https://www.meteoromania.ro/

A *Red Warning Alert* was issued by ANM, citing the phenomena that eventually occurred in the mentioned areas (fig. 7, right). The damage was significant, caused by large hail, and also by high amount of accumulated precipitation in a short period of time, as a result of which the city's sewage system overflowed, thus causing significant flooding in the center of Zalău and other neighboring localities.

At 12:50 UTC, the supercell reached the south-west border of Maramureș county and after 30 minutes, the city of Baia Mare (fig. 8, left), where the radar images shown reflectivity values of over 65 dBZ (fig. 8, right), and a slight attempt of a hook echo. Hail, strong wind gusts, heavy rain and lightning strikes were registered in Baia Mare, too, causing significant damages.

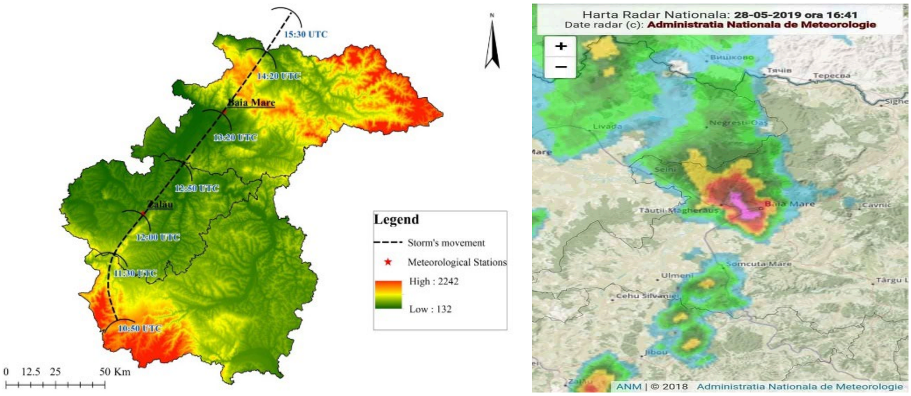

Fig. 8. Supercell's path from genesis to dissipation (left), and Radar Reflectivity-Romanian National Map (right), on 28th May 2019
Source: https://www.meteoromania.ro/radarm/radar.index.php

Only 3 hours and 30 minutes after its appearance, the supercell left the territory of Romania, heading north-north-east, in Ukraine. The storm intensity weakened in the border region and it dissipated in the Wooded Carpathians (Ukraine), at around 15:30 UTC. It should be mentioned that throughout the analyzed period, a lot of convective cells developed in the Western regions of Romania, some of them evolving to supercells.

3.2. Phenomena and impact

The reported meteorological phenomena generated by the supercell's evolution over the region, were: heavy rain showers, frequent lightnings, strong wind gusts, hail of various sizes (diameter between 1-6 cm) (fig. 9, left).

As a result, the following damages reported both by the public in various reports and by the local press, were registered (fig. 9, right): flooding water infiltration into homes, streets blocked by the large volume of existing water, damage and destruction of roofs or chimneys, damaged/destroyed cars, broken windows or windshields, trees blown down by the wind, power outages.

Fig. 9. Hailstones over Zalău (left), Damages due to severe wind gusts over Baia Mare (right), on 28th May 2019.
Source: (right) https://www.emaramures.ro/imagini-apocaliptice-in-maramures-furtuna-si-grindina-au-facut-prapad-foto/

Regarding the meteorological phenomena measured/observed, *The European Severe Weather Database* platform (ESWD) published the following reports (https://eswd.eu/cgi-bin/eswd.cgi): 7 reports of medium and large hail, 2 reports of excessive precipitation, 6 reports of strong wind gusts. According to http://www.meteomanz.com/, the meteorological weather stations situated on the supercell's path (fig. 8, left) recorded the phenomena listed in Table 1.

Table 1. Supercell's meteorological phenomena registered by Zalău and Baia Mare weather stations, on 28th May 2019

Weather station/ Weather data	**Zalău**	**Baia Mare**
Maximum wind gust (km/h)	39.6	104.4
Maximum hail diameter (cm)	3.5 (6.0 from local sources)	4.0
Accumulated precipitations (mm)	13.0	16.2

Source: http://www.meteomanz.com/

More information regarding the risk meteorological phenomena generated by the supercell's evolution in Sălaj and Maramureş counties were found in the local media:

- "Several roofs were damaged and several car windshields were broken, on Tuesday, following a hailstorm in Sălaj County, which was under a code red warning issued by the ANM." (https://ziare.com/stiri/cod-rosu/imagini-incredibile-din-zalau-unde-a-fost-cod-rosu-de-grindina-care-a-produs-pagube-importante-video-1563345);

- “Hail fell for several minutes in several localities in Sălaj County and caused substantial damage. The pieces of hail were the size of a chicken egg or even bigger, and the captured images were quickly posted by locals on Facebook.” (https://ziare.com/stiri/cod-rosu/imagini-incredibile-din-zalau-unde-a-fost-cod-rosu-de-grindina-care-a-produs-pagube-importante-video-1563345);
- “There were seven calls for small, medium and large hail. Damage to roofs, houses, broken car windshields were reported. An assessment of the situation is being made," said Lucian Jacodi, the spokesperson of the ISU Salaj.” (https://ziare.com/stiri/cod-rosu/imagini-incredibile-din-zalau-unde-a-fost-cod-rosu-de-grindina-care-a-produs-pagube-importante-video-1563345);
- “For approximately 40 minutes, the city of Baia Mare was under code red for dangerous meteorological phenomena. During the 40 minutes, the hail and the wind wreaked havoc in the city.” (https://adevarul.ro/stiri-locale/baia-mare/foto-imagini-apocaliptice-furtuna-a-facut-ravagii-1946928.html#gal=230b4f6f-63f7-4adf-95d5-3e8bb2da1532&gal_i=4&gal_fs=0);
- “The windshields of dozens of cars were broken, but also the block roofs were blown up by the strong gusts of wind.” (https://adevarul.ro/stiri-locale/baia-mare/foto-imagini-apocaliptice-furtuna-a-facut-ravagii-1946928.html#gal=230b4f6f-63f7-4adf-95d5-3e8bb2da1532&gal_i=4&gal_fs=0);
- “Hail destroyed the roof and skylights of the "Corneliu Coposu" secondary school in Zalău. Due to the destruction, classes for students at this educational unit were suspended on Wednesday. Builders assisted by firefighters are working to make the building safe so that classes can resume on Thursday, May 30.” (https://www.libertatea.ro/stiri/cod-rosu-de-tornada-in-judetul-salaj-2648483).

Based on the data collected by a local source from Baia-Mare (https://adevarul.ro/stiri-locale/baia-mare/foto-imagini-apocaliptice-furtuna-a-facut-ravagii-1946928.html#gal=230b4f6f-63f7-4adf-95d5-3e8bb2da1532&gal_i=4&gal_fs=0), a brief analysis was carried out on the damage generated by the severe convective structure within the city’s area (Table 2).

Table 2. Statistics of damages in Baia Mare

No. crt.	Damage type	No.
1	Destroyed/damaged roofs	18
2	Blown down trees	> 100
3	Immobilized vehicle	1
4	Broken windshields	> 10
5	Affected power lines	5
6	Power outage	3.313
7	Restricted traffic lines	1
8	Flooded streets	3

Source: mentioned above

It can be seen that, due to the magnitude of the phenomena, the impact on the environment and even the performance of any type of activity was inevitably high: real estate, agricultural, road, electricity and automotive sectors were affected.

4. CONCLUSIONS

The supercell that affected Sălaj and Maramureş Counties on May 28th 2019, had a significant impact generated by synoptic and mesoscale conditions for this kind of storms to form and evolve. The result to this context was a strong supercell that represented a threat for the areas of Salaj and Maramures counties, including the cities of Zalău and Baia Mare which were seriously damaged after the storm passed.

Severe impact was imminent and led to dozens of damages including floodings, affected buildings and destroyed vehicles, power outage due to lightning strikes and especially significant destruction because of the large hail. Storm's manifestation resulted in panic among the population. The atmospheric phenomena had a somewhat more unusual intensity for this region of Romania, as they rarely occur at this intensity.

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