SYNOPTIC PROCESSES GENERATING WINDTHROWS. A CASE STUDY IN THE APUSENI MOUNTAINS (ROMANIA)

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ABSTRACT:
Windstorms are among the main factors causing damages to forest ecosystems. These meteorological phenomena cannot be predicted, prevented or controlled. They are occurring rapidly and take place in a meteorological context characterized by high velocities of the air currents. This paper analyses the characteristics of the severe meteorological events on 20 July 2011 which have led to windthrows on extended areas within the Apuseni Mountains in the Romanian Carpathians. The study highlights the evolution of the synoptic processes both at regional scale and at mesoscale. The meteorological analysis is carried out based on synoptic maps and by means of the data coming from the doppler WSR-98D radar in Bobohalma. The main results indicate the occurrence of the severe meteorological phenomena against the background of alternating atmospheric circulation types. The main cause is the transition of the zonal circulation into maritime tropical circulation. This contributed to the destabilizing of the warm and moist air masses that have generated strong storms at national level

Key-words: *Synoptic processes, Windthrows, Wind gusts, Radar images, Romanian Carpathians.*

1. INTRODUCTION

Over the last decades, windthrows have increased both in size and in frequency. The researches on future climate changes predict the enhancement of the extreme meteorological phenomena (windstorms) over the following decades (Thom & Seidl, 2015).

The causes of windthrows are both natural and anthropogenic. Many factors (meteorological, topographical, biological, and edaphic) interact simultaneously and influence the damage patterns and the recovery dynamics of these damages. As an ecological factor, the wind is no longer seen as a simple disturbance force, but as a spatial disturbance agent that causes significant damages to the forest vegetation. It affects more aspects of the disturbed forests such as community structure, individual tree growth, tree regeneration, and species diversity (Xi, 2005).

Scientific investigations estimate that approximatively 0.12% of the volume of European forests is disturbed every year (the average value for the 1950-2010 interval, after Schuck & Schelhaas, 2013).

The forests in the Carpathian Mountains represent the largest temperate forest in Europe. They are composed of beech and mixed forests, but also of many areas with spruce

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monocultures (Griffiths et al., 2014). The latter have a high vulnerability to windthrows. Windstorms are responsible for more than 50% of the damages caused to the European forests both by the biotic and by the abiotic factors (Gardiner et al 2011). The natural disturbances in the Carpathian Mountains are greatly caused by wind and snow, but forests are frequently affected also by pests, insects and industrial pollution (Oszlanyi, 1997).

Recent studies indicate that more than 28% of the forest areas in the Romanian Carpathians are vulnerable to windthrows (Savulescu & Mihai, 2012). The increase of forest vulnerability to windthrows is influenced also by forest management (Schuck & Schelhaas, 2013). Forest exploitation in Romania has intensified during the communist period (Grozavu et.al, 2012). This led to the fragmentation of the native species which have been replaced by spruce cultures, exploited for timber production (Munteanu et. al, 2014).

The main cause of the disturbances in the Romanian Carpathians is represented by windthrows (Anfodillo et al., 2008), although the extreme wind meteorological events occur once every 10-15 years (Popa, 2008). Most of the windthrows are diffuse, small scale (Costea et al., 2012; Furtuna et al., 2016). Some of them are not even being registered in the forest management books. However, greater attention was paid to windthrows in the Apuseni Natural Park caused by strong winds and storms (Costea & Haidu, 2010; Furtuna, 2017).

The reason for this study is given by the yet increasing frequency of windthrows in the Apuseni Mountains and by the intensification of extreme meteorological phenomena leading to their occurrence. Their effects are directly connected to the pressure of the wind on the brushes and by the amount of rainfall during the meteorological phenomenon. However, since 2011 there have been recorded no windthrows of such amplitude in the Apuseni Mountains.

The main objective of this study is to analyse the characteristics of the severe meteorological events on 20 July 2011 that have led to windthrows on extended areas within the Apuseni Mountains. The paper analyses to what extent is the severe weather capable of generating significant windthrows. At the same time, the paper highlights the evolution of the synoptic processes both at regional scale and at mesoscale. Understanding the interaction process between wind and forest vegetation, as well as the impact of the damages caused by the wind, is important in forest management in order to establish and implement some sustainability policies.

2. DATA AND METHODS

The analysed area is located in the north-eastern part of the Alba county, with the following coordinates: 46°21´N and 23°02´E (**Fig. 1**), overlapping the Muntele Mare and Trascău Mountains and the Câmpeni lowland area.

The climate features are directly influenced by the geographical position. The annual temperatures are closely connected to the local morphological specificities. Hence, the channelling of air and low temperature on the Arieș Valley, especially during winter, leads to lower temperatures (Maier, 2011).

The vegetation in the area is specific to the hill and mountain regions, composed of mixed {beech (Fagus Sylvatica), fir (Abies Alba) and spruce (Picea Abies)} forests. The area affected by windthrows is located at altitudes ranging between 800-1200 meters, composed of coniferous (especially spruce) and broad leaf forests.

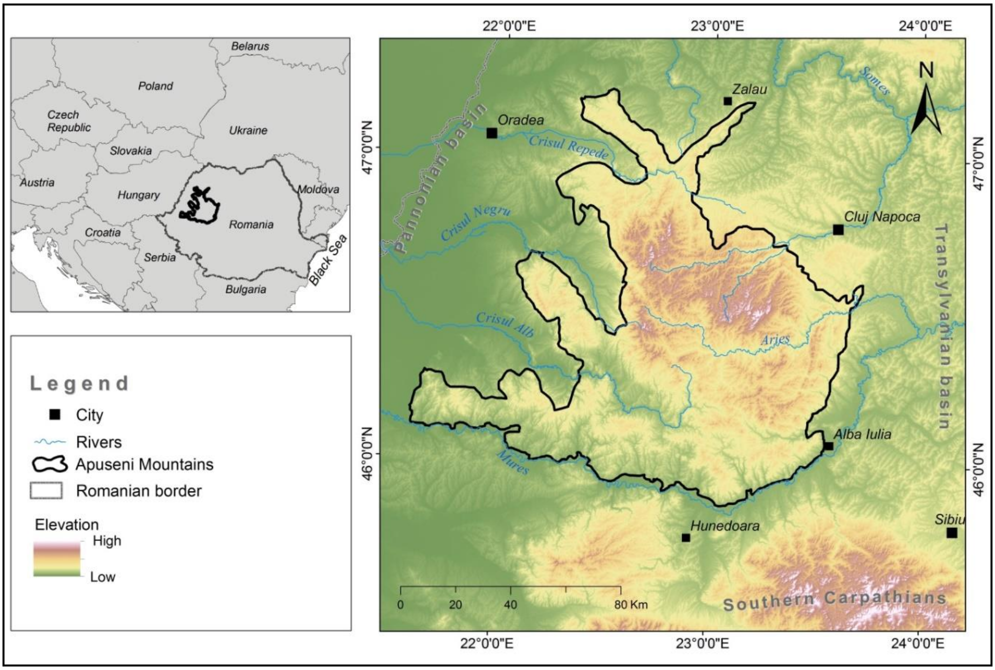

Fig. 1. Location of the study area (source Furtuna, 2017).

The methodology used for this study focused on the synoptic analysis of the meteorological conditions of the windthrows on 20 July 2011. Yet, the first stage of the study has implied the detection of the areas affected by windthrows. Based on the data referring to the extreme weather event on 11 July 2011, Landsat satellite images were used for the period before and after the meteorological phenomenon. The Landsat sensors are a useful tool for ensuring the images necessary for the assessment and monitoring of the changes induced to the forest vegetation (Vogelmann et al., 2012). The Landsat images have been pre-processed to calculate the root mean square error (RMSE) for the two images that were used and to convert the digital numbers into the surface reflection according to the established methodologies (Furtuna et al., 2015; Haidu et al., 2017).

The detection of the changes occurred in the forest vegetation after the storm (**Fig. 2**) was carried out based on the calculation of the difference between the NDVI index calculated for the image before and after the storm, respectively.

The synoptic analysis was carried out based on the synoptic maps of the European continent, the maps of the pressure field at soil level, the maps of the geopotential and temperature field of the National Oceanic and Atmospheric Administration http://www.esrl.noaa.gov and DWD - Deutscher Wetterdienst *www.wetterzentrale.de*.

In the case of sub-synoptic scale (mesoscale) or storm scale analysis, data from the Doppler WSR-98D radar in Bobohalma (Mureș county) were used. In order to determine the movement direction and the speed of storm movement, thematic radar images were used such as reflectivity, images of the convective storms movement speed, of the Vertically Integrated Liquid water (VIL), and of the cloud masses height.

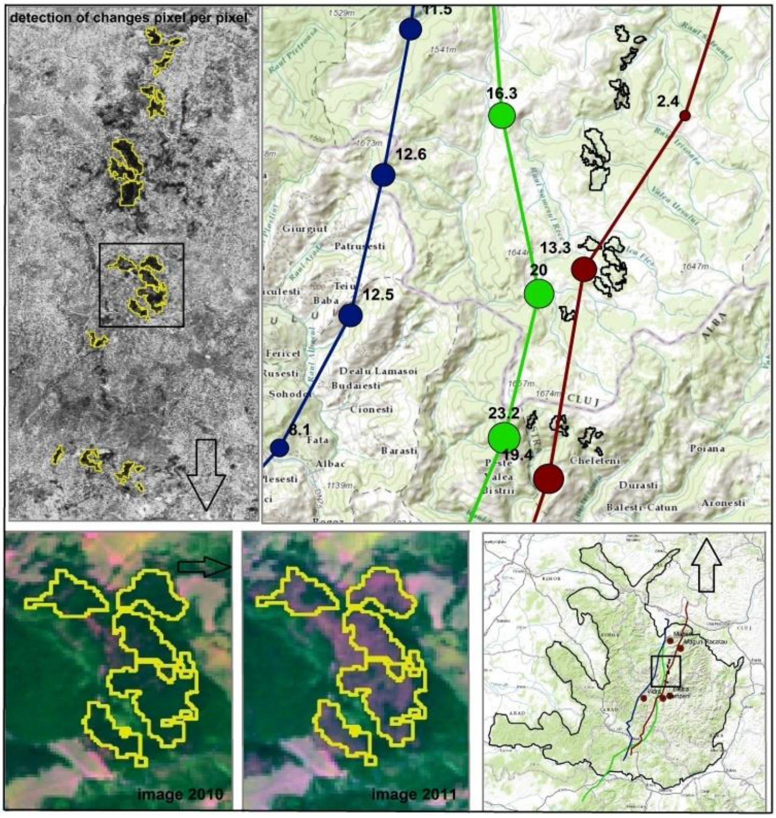

Fig.2. The detection of the areas affected by storm, as well as the paths of the convective phenomena.

When calculating the speed of wind gusts, we used the corresponding values of VIL and ET applied in the formula used also by the researchers at Air Force's Air Weather Service (1996).

$$W= [(15.780608 \cdot VIL) - (2.3810964 \cdot 10^{-6} \cdot ET^2)]^{1/2} \text{ (AWS, 1996)}$$

where: VIL is the vertically integrated liquid water volume [$kg \cdot m^{-2}$], ET is the height of the cloud (echo) [km].

The analysis methodology of the synoptic situations was carried out by means of the images with the tempo-spatial evolutions of the VIL product, extracted from the values of storm cores and superimposed over the rainfall areas. This methodology brings additional useful information in order to determine the paths of the convective phenomena depending on the moisture load and speed of travel.

3. RESULTS AND DISCUSSION

The synoptic conditions that generated the significant amounts of rainfalls and storms on 20 July 2011 leading to windthrows on more than 120 ha of forests in the Apuseni Mountains were caused by the intensification of the cyclonic activity.

The synoptic situation before the occurrence of the 20 July storm was characterized by western atmospheric circulation above our country. This synoptic configuration persisted, with slight variations, from 15 July until 19 July **(Fig. 3)**. It was characterized by a hot and dry period, with temperatures exceeding 35°C.

Following the geopotential field at the 500 hPa isobar level, the altitude difference can easily be identified, with a well highlighted core in the north of Europe, characterized by a pressure in the 995 hPa centre. A secondary core with 1000 hPa pressure is located in the centre of Europe, also affecting western Romania on 20 July.

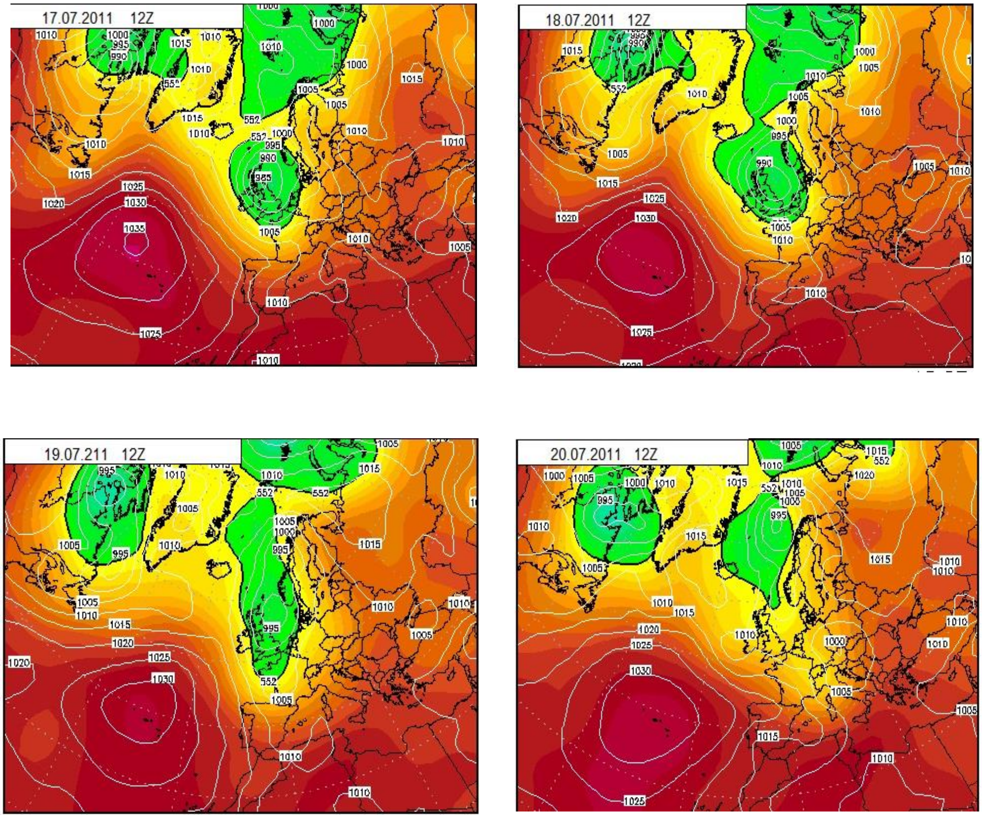

Fig. 3. The geopotential field at the 500 hPa (550 m) isobar level, the 17-20 July 2011 interval. *(source: www.wetterzentrale.de)*

The geopotential field configuration at the 500 hPa isobar level indicates a low value of the geopotential of only 5720 mgp. Based on the structure of the air temperature field at the 850 hPa level, the Western Romania fits within the 17°-18° range **(Fig. 4)**.

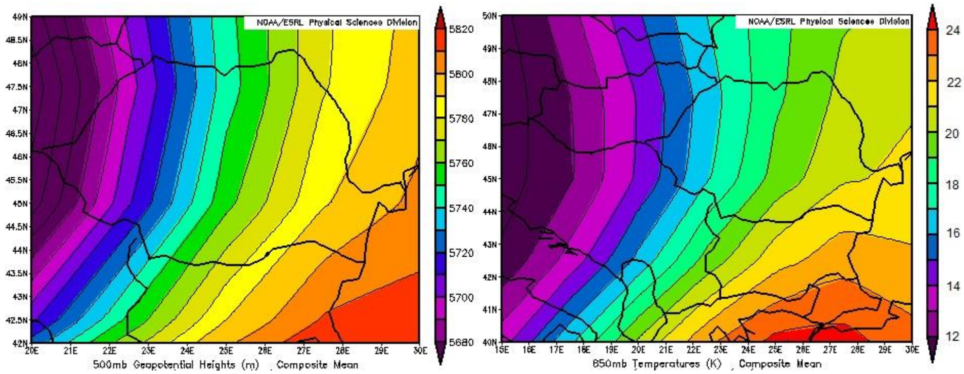

Fig.4 The geopotential field at 550 hPa and the structure of the air temperature field at 850 hPa level for the Romanian territory (processed by means of http://www.esrl.noaa.gov) for the day 20.07.2011.

The baric situation over Europe indicates the presence of an anticyclonic field at the ground level over the Western Europe and in the north of Africa. The rest of the continent was dominated by a cyclonic field, with a core located in the Pannonian Plain and the west of Romania with the 998 hPa pressure **(Fig. 5)**.

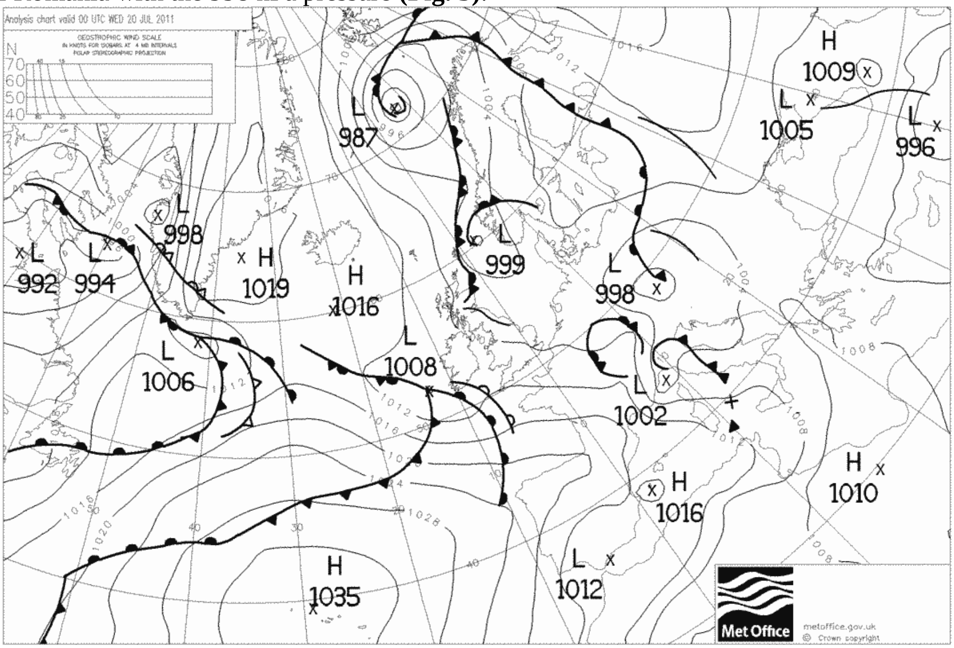

Fig. 5. The atmospheric pressure front on 20.07.2011, at 00.00, at sea level.
(*source: www.wetterzentrale.de*)

On 20 July, the transition of the zonal circulation into maritime tropical circulation, contributed to the destabilizing of the warm and moist air masses that generated strong storms at national level.

Windthrows were caused by the convective descending movements which were associated with the increase of the cumulus clouds and the development of storms (Furtună et al., 2013). Although convective winds occur suddenly and violently, these have a short duration and determine violent occurrences of meteorological phenomena at soil level.

The day of 20 July starts with a pre-front instability. The first D0 wind gust started around 12:00 GTM **(Fig. 6)**, being formed in the Zarand Mountains area. The wind gust increases in intensity with the movement to the north, reaching the speed of 23 m/s south of Vidra village.

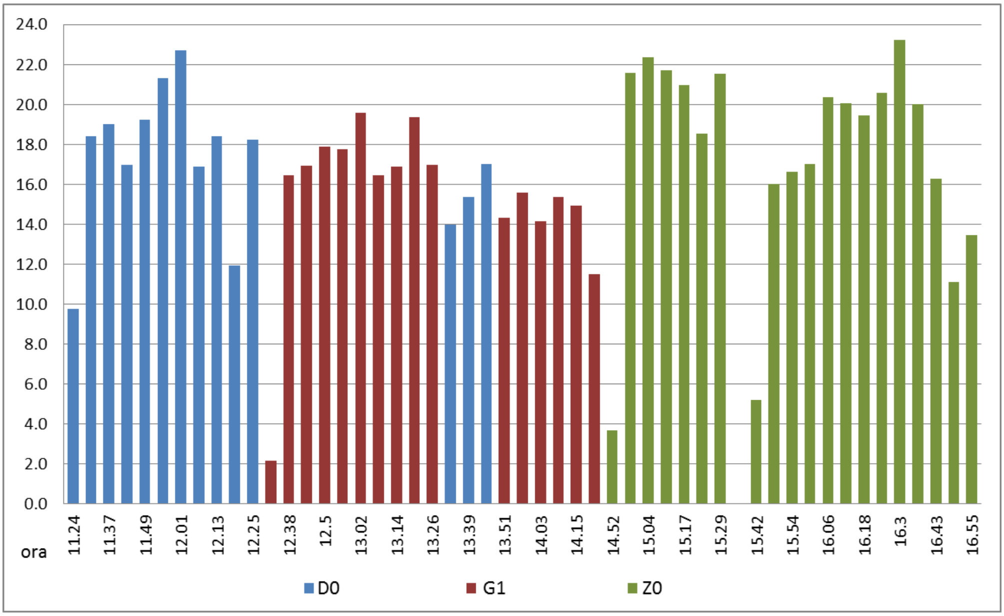

Fig. 6. The speed of wind gusts and the time interval they took place.

The second wind gust, G1, developed around 12:30 and had constant speeds, which did not exceed 20 m/s. This speed was recorded when the gust crossed the town of Câmpeni, where the windthrows occurred.

The Z0 wind gust was formed in the Poiana Ruscă Mountains area. It was stronger in intensity; it exceeded 23 m/s in the area of Câmpeni and Bistra localities when it reached the mesocyclon level (MESO - indicates the existence of wind shears within the storm). The mesocyclone is associated with a lower pressure region located in a severe storm and generating tornadoes. Such storms are characterized by strong surface winds and hail. The wind gust has lost its intensity when meeting the mountain range blockage in the Muntele Mare area **(Fig. 7)**.

The graphical form of the storm core path indicates the air circulation from the lower troposphere to the middle one, i.e. from the south-east to the north-west **(Fig. 7)**. The strongest gusts recorded speeds higher than 23 m/s when crossing the affected area.

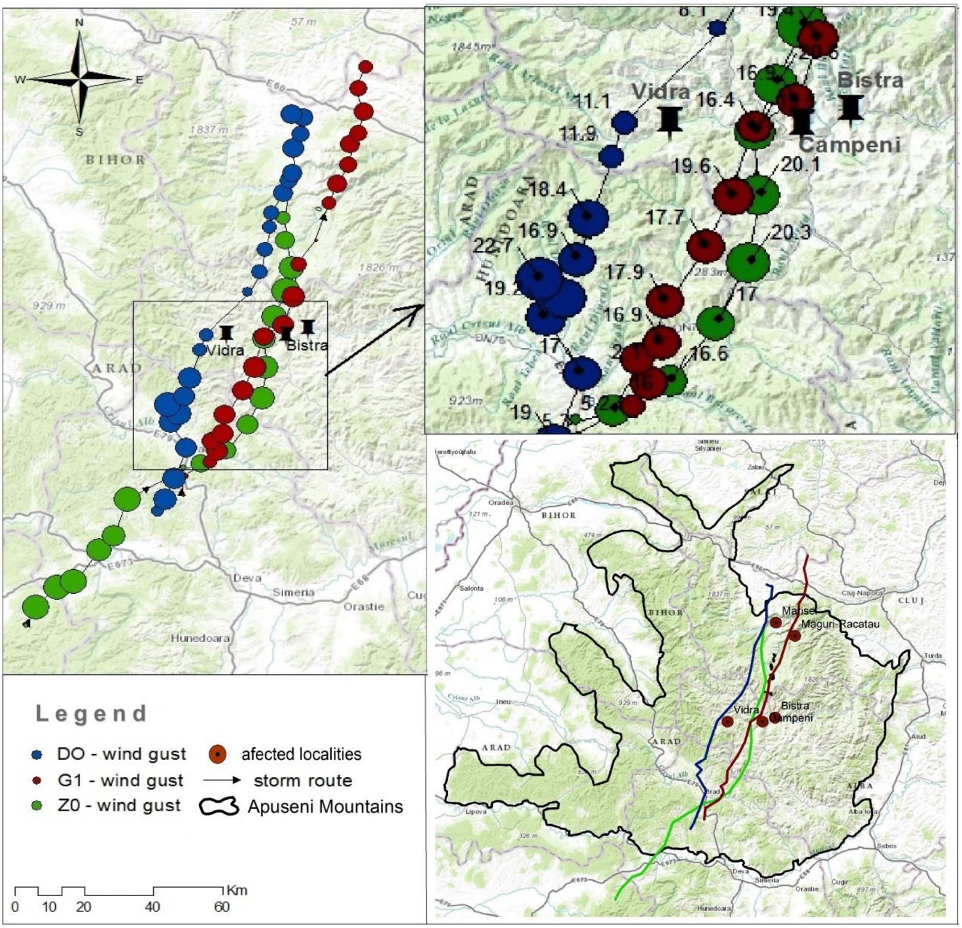

Fig. 7. The trajectory and speed of the wind gusts in the area affected by windthrows.

After this storm episode, the instability gradually decreased during the night of 20-21 July, when a new hot and dry period started.

4. CONCLUSIONS

The synoptic situation of the storm that caused windthrows on more than 150 ha of forest was favoured by the alternating atmospheric circulation types. This created a favourable context for the formation of convective cells. The windthrow was caused by the descending convective movements. All these high-altitude cold air convections remained on the valleys and caused windthrows.

The calculation of the gusts speeds by means of VIL and ET corresponding values enabled us to determine the paths of the convective phenomena and their speed of travel. The three cores had a travel direction from the south-eastern to the north-eastern sector, crossing the Apuseni Mountains. In terms of meteorological risk, the windthrow on 20 July 2011 was characterized by the occurrence of the short-term wind gusts at speeds higher than 23 m/s (almost 90 km/h).

The Apuseni Mountains area can become the stage of such phenomena whenever the zonal circulation turns into maritime tropical circulation. The instability of the warm and moist air masses is favoured by the fact that the mountains are surrounded by low lands (the Western Hills and Plain, the Transylvanian Plateau, the large corridor of the Mureş River). The elevational gradient conferred by the sudden transition to high altitudes is very important.

The morphography of the Apuseni Mountains is characterized by the high fragmentation of the landforms. This is achieved by embedding the “gulf depressions”, the depressions inside the mountain range, the saddles and the large and deep valleys, which facilitates the formation of some storm corridors which are not stopped when meeting higher and more compact massifs. The mountain crests appear under the form of some suspended erosion platforms steps, rather plane, which also facilitate the sliding of the air and the wind travel. Under these morphographical conditions, the high-altitude cold air convections have installed and intensified along some valleys and saddles on a south – north trajectory and have caused windthrows. It would be interesting to study in the future which is the occurrence frequency of these storm trajectories and whether preferential travel corridors could be identified depending on the elevation baric configuration.

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