INCREASING THE RISK OF TORNADOES IN ROMANIA DUE TO CLIMATE CHANGE

CREŞTEREA RISCULUI DE APARIŢIE A TORNADELOR ÎN ROMÂNIA DATORITĂ SCHIMBĂRILOR CLIMATICE

BODALE I.[1], CAZACU Ana, ENEA Elena-Andreea, OANCEA Servilia
e-mail: ilie.bodale@uaiasi.ro

Abstract. *The aim of this paper is to analyze the causes that lead to the emergence of tornadoes in very low risk areas (Romanian territory) in the conditions of the climatic changes of the last 100 years. This extremely violent meteorological phenomenon is generated by very specific metrology conditions which make the likelihood of their occurrence to be low. The relationship between the occurrence of tornadoes in tornado-free areas and global warming is still unclear. In the present paper we have made a comparative study to estabilished if the whether condition which generated the Facaeni tornado, in 2002, was random occurrence or was generated by the warming of the atmosphere in terms of climate change. The study is based on the analysis of the factors that generated the tornado, the geographic position, the climate of the region and the warming athmosphere over the last 55 years. Our analysis established that Facaeni tornado was EF3 intensity and represents a turning point in the study of tornadoes in Romania*.
Keywords: tornadoes, extreme phenomena, Facaeni tornado, global warming, climate change

Rezumat. *Scopul acestei lucrări este de a analiza cauzele care duc la apariţia tornadelor în zone cu risc foarte scăzut (teritoriul României), în condiţiile schimbărilor climatice din ultimii 100 de ani. Acest fenomen meteorologic deosebit de violent este generat de nişte condiţii metorologie foarte specifice ceea ce face ca probabilitatea apariţiei lor să fie scăzută. Relaţia dintre apariţia tornadelor în zone considerate lipsite de tornade şi încălzirea globală sunt încă neclare. În prezenta lucrare am făcut un studiul comparativ pentru a stabili dacă apariţia tornadei în Făcăeni, din 2002, este o întâmplare sau apariţia a fost generată de încălzirea atmosferei în condiţiile schimbărilor climatice. Studiul se bazează pe analiza factorilor care au generat tornada, poziţia geografică, clima regiunii şi modificarea temperaturii aerului în ultimii 55 ani. Analiza noastra a stabilit ca la Făcăeni în 2002 tornada a fost cu intensitatea EF3 ceea ce reprezintă un punct de cotitură în cea ce priveşte studiul torndatelor în România.*
Cuvintecheie: tornade, fenomene extreme, tornada Făcăeni, încălzire globală, schimbări climatice

[1] University of Agricultural Sciences and Veterinary Medicine Iasi, Romania

INTRODUCTION

In the last years, extremely wheather phenomena become a permanent threat to the security of the population and property. From 1980 till 2000 the estimation is that 75% of population of whole would were affected at least once by such phenomenon (tropical cyclone, tornado, flood, drought etc) (Teodorescu *et al*., 2007). The numbers of irregular winds have increased cause material damage and loss of life. This type of winds can be classified as: tropical cyclones, hurricanes, typhoons or tornadoes (Colda and Ardelean, 2004). These winds are caused by large temperature differences between the air mass and the Earth surface. Where the wind is form above a large stretch of water is called: *hurricane* (Povară, 2004) and if it's generated above the terrestrial surface is *tornado* (Wurman, 2008). The tornado is a vertical column of air from Earth surface till a *Cumulonimbus Clouds* which is moves with high speed and counter clockwise rotating, in Northern Hemisphere (Garrison, 2012). The most tornadoes in the world form a spiraling funnel-shaped wind current, about 80 m diameter, with moves at least with 180 km/h, several kilometers. However, few of them can attain F5, with 480 km/h wind speed, a funnel larger the 2 km diameter and travels on the ground more than 100 km.

Tornadoes occur due to excessive warming of the air from the ground surface which is training them in a swirling motion upwards. At vertical climbing, the air is getting cold and part of water vapors condens into *Cumulonimbus Cloud.*

From a climatological point of view, tornadoes occur across the globe less at the poles. In Europe, tornadoes can occur in central-west part (Grünwald and Brooks 2011). The European countries where annual tornadoes can appar, even F4-F5 intensity, are France, Belgium, the Netherlands, Germany and Poland. In Romania, the Czech Republic, Bulgaria, the Republic of Moldova, Greece and Spain are countries where tornadoes can reach the F2 intensity. Instead, in Serbia, Macedonia and Bosnia Herzegovina are areas in Europe where tornadoes do not appear or they have very low intensities (fig. 1).

During the day, the most frequent tornadoes occur afternoon around 5.30 PM or the violent tornado later one hour (Snow 2009). In figure 2, we included a tornados season map during the year in Europe, where in central and northern has the maximum in mid-summer (July) and in the mid-autumn (October) in the sorth (Groenemeijer and Kühne, 2014).

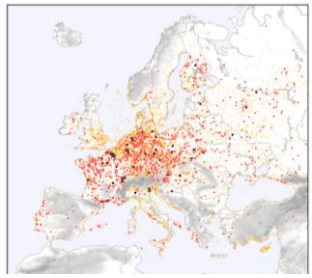


Fig.1 Tornados in Europe (F0-F1 yellow, F2-F3 red and F4-F5 black spots)

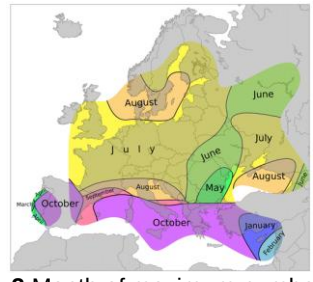


Fig.2 Month of maximum number of tornado in Europe

In 1971, Theodore Fujita proposed a classification system of tornadoes based on destruction of construction (Fujita, 1971). Started from 2007, USA adopted Enhanced Fujita Scale (EFS) classification which describes better than the Fujita scale the impact on the environment. This scale uses 28 indicators for storm damage and changes the speed values for different degrees of storm (Dotzek, *et al.,* 2009).

In the last years, in scientific community there is a debate regarding the relation between increasing the incidence of tornadoes and the whether climate change (Hurricanes, 2015). After 2000, it was raported an incresing number of tornados in regions considered with risk of occurrence. Moreover, tornadoes with F3 intensity were reported in country where they did not meet, like Romania, the Czech Republic and Spain (Lacinová *et al.,* 2007).

MATERIALS AND METHOD

We performed a climatological analysis of tornado occurrence in the conditions of climate change by using the European Severe Weather database and European Climate Assessment & Dataset in Romania. We developed a program in FORTRAN language able to calculate the annual and half-decade averages in each of the 5 metrological stations and used OriginPro for data processing.

RESULTS AND DISCUIONS

In this paper, we studied if high-intensity tornadoes occured in regions with limited risk of emergence, like Facaeni in 2002 (Balteanu *et al.* 2004, Lemon *et al.,* 2003) was caused by global warming or climatic hazard. In this way, we analyzed the natural condition where the tornado blow and compared the occurrence of tornadoes with the change of average air temperatures from 1961 to 2017, in Romania (Ivanescu *et al.,* 2016).

This tornado had a maximum impact in Facaeni (coordonate: 44°33′46″N, 27°53′38″E) that is a small commune in the East of Ialomita county. The relief in this region is dominated by tabular plain (Baragan Plain) and meadow of Borcea branch of Danube. The maximum altitude does not exceed 100 m (Hagien Plateau) and the lower is 3 m at the confluence of Danube and Ialomita rivers. The position of this locality makes a harsh climate, with hot and dry summers but with cold and bizzard winters. The annually average value of temperatures is around 11.5°C.

The air temperature changed in Romania was analized for recorded values from 1961 to 2017, using date from five weather stations in the country (Bucharest, Constanta, Iasi, Cluj-Napoca and Arad) measured by *Administraţia Naţională de Meteorologie* (ANM) (Tank *et al,.* 2002). The annually, respectivly half-decade avarage air temperature is increasing in the last decade with 0.72^{o}C compared to 55 years ago (Ivanescu *et al.*, 2016).

From 1950 to 2013, European Severe Weather Database (ESWD) contains reports of 9529 tornadoes in Europe (Figure 1), where the numbers of them strongly increasing after the mid of 1990s, reaching a peak (680 tornados) in 2006 (Dotzek *et al.,* 2009, Groenemeijer and Kühne, 2014). In Romania, the first reported

tornado was in 1822 (Timisoara) and today we have 126 reported from which 89 after 1990. This represents an increasing of 7 times over the last quarter of a century.

Meteorogical conditions which have produced the tornado

In Facaeni, the dominate wind is Crivat that blows from North–Este (Fig.1) but in the last 15 years there were reported two strong thunderstorms (August 2002 and May 2017). In this paper, we focused on thunderstorm from August 2002 (Figure 4) with become a tornado in Facaeni and represent a turning point regarding tornado activity in Romania.

Analysis of the synoptic and the mesoscale state

Synoptical analysed of extremly whether phenomena associated with tornadoes was performed base on the numerical mesoscale ALADIN model.

During the analyzed period a large part of Europe was affected by storms, torrential rains and floods, included Romania. The synoptic outlook on Europe was characterized by a quasi-stationary depression and a middle-level blocking ridge in Eastern Europe.

Below the middle-level blocking ridge there was a low-level counter cyclone that created an air stream in South-Eastern across the Eastern regions of the Balkan Peninsula. Meanwhile, a surface depression over Western Europe had a slower movement to South-East, reaching the Slovak Republic on August 12th. In Bulgaria and Romania, this phenomenon has produced a warm advection structure which has also transported high humidity.

Mesoscale features also played an important role in determining the evolution and convection type. The basic components were moisture, instability, heightening mechanism and others.

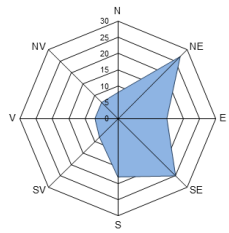
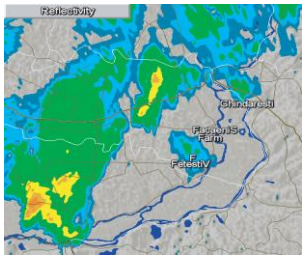


Fig.1 Annual Windrose in Facaeni

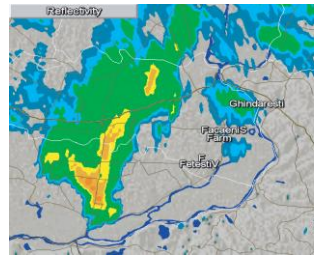
(a)

(b)

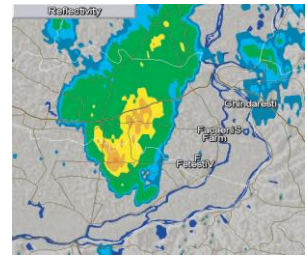
Fig.4 Tornado Facaeni, August 2002



RADAR image: at 4.00PM



at 4.10PM



at 4.20PM

Fig.5 State of the atmosphere in Facaeni region recorded by ANM radar

Above South-Eastern Romania, the interaction between air current and topography created a specific convergence zone. The result was an unstable, warm and wet air cleat on Earth surface extending up to the 850 mb isobar. Convergence persisted for more than 12 hours and result a thermal gradient with moisture along this convergence line. The warm and wet air mass remained stationary in front of the approaching cold front. Moreover, when the short wave approached from Western Europe the atmospheric flow, called *Convective Available Potential Energy* (CAPE), ranged from 2000 to 3000 J/Kg along the convergence line. This low-level destabilization and the near-coming short wave initiated the tropospheric shear.

Similarly, the atmosphere in Bulgaria was unstable with a CAPE of about 3300 J/Kg or even more. Whereupon, it was resulted a medium and superior wind with speed more than 30m/s which creating shearing for super-cells. Besides this, a higher level dry intrusion formed above wet area. All these meteorological events have generated the super-cell storm from Facaeni.

Until 4.00PM, the storm has developed a "hook echo" as described in figure 5, recorded by ANM radar. Our analyse estimated that the shape of the funnel of tornado, surprised by Marius Paun photograph (fig. 4b), touch the ground between 4.10PM to 4.20PM (fig. 5). However, until 16.20 it is almost certain that the tornado was on the ground in the form of "hook echo".

Our results claim that the tornado from Facaeni, on 12th August 2002, was F3 grade on Fujita scale. Tornada had wind speed 252-330 km/h, lasted about 2 minutes, with 1 km diameter of funnel and traveled 74 km. During the tornado, 33 houses were completely destroyed, 395 houses were partially destroyed, 14 people were seriously injured, 3 people died and 120 ha of acacia forest was destroyed by breaking trees.

Wind speed for several degrees of damage (DODs) was performed using below relation able to convert the wind speed from Fujita scale (FS) into Enhanced Fujita scale (EFS):

$$EFS = 0.6246\ FS + 36.393$$ (McDonald and Mehta 2006).

The EFS wind speed of EF3 tornado from Facaeni (2002) was calculated by us at 194-243 km/h based on above formula and impact of tornado on each element.

Our analysis shows that global warming increases the intensity and frequency of extremely weather phenomena. We calculate that in Romania the temperature avarage of last decade increasing to 1960s decade with 0.72^{o}C. Moreover, these can occure in areas that did not have climate risk before the 1990s.

CONCLUSIONS

We performed a climatological analysis of tornado occurrence in the conditions of climate change by using the European Severe Weather database and European Climate Assessment & Datasetin Romania. Tornado from Facaeni, on 12th August 2002, was F3 grade on Fujita scale lasted about 2 minutes, 1 km

diameter, wind speed was 194-243 km/h and traveled 74 km. Tornado affected one fifth of total population of locality.

The complex methorological conditions needed to generate a tornado with high intensity (bigger the F2) can be repeated in Romania, especially Dobrogea and the Romanian Plain.

REFERENCES

1. **Balteanu D., Stan-Sion A., Cheval S., Trandafir P., Dobre B., Râmniceanu V., Dragne, D., Micu, M., Damian, N., Costache, A., 2004** - *Hazarde naturale şi tehnologice în România. Tornada de la Făcăeni din 12.08.2002,* Bucharest.
2. **Colda I., Ardelean F., 2004,** - *Meteorlogie şi climatologie*, Bucharest, Conspress Publisher.
3. **Dotzek N., Groenemeijer P., Feuerstein B., Holzer A.M., 2009** - *Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD*, Atmospheric Research, 93(1): 575-586.
4. **Groenemeijer P., Kühne T., 2014** - *A Climatology of Tornadoes in Europe: Results from the European Severe Weather Database*, Monthly Weather Review, 142(12): 4775-4790.
5. **Grünwald S., Brooks H., 2011** - *Relationship between sounding derived parameters and the strength of tornadoes in Europe and the USA from reanalysis data*, Atmospheric Research 100 (2011) 479–488.
6. **Ivanescu L., Bodale I., Florescu S.A, Roman C., Acatrinei D., Miron L., 2016** - *Climate Change Is Increasing the Risk of the Reemergence of Malaria in Romania*, BioMed Research International,vol 2016, 1-7.
7. **Tank A.K., Wijngaard J.B., Konnen G.P., Bohm R., Demaree G., Gocheva A., Mileta M.,Pashiardis S., Hejkrlik L., Kern-Hansen C., Heino R., Bessemoulin P., Muller-Westermeier G., Tzanakou M., Szalai S., Ottir T.P., Fitzgerald D., Rubin S., Capaldo M.,. Maugeri M, Leitass A., Bukantis A., Aberfeld R., Van Engelen A.F., Forland E., Mietus M., Coelho F., Mares C., Razuvaev V., Nieplova E., Cegnar T., Lopez J.A., Dahlstrom B., Moberg A., Kirchhofer W., Ceylan A., Pachaliuk O., Alexander L.V., Petrovic P., 2002** - *Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment*, International Journal of Climatology, 22(12): 1441-1453.
8. **Lacinová M., Munzar J., Franc M., 2007,** - *Newly identified historical tornadoes in the Czech Republic from 16th to the 20th centuries*, Atmospheric Research 83(2): 488-492.
9. **Lemon L.R., Stan-Sion A., Soci C., Cordoneanu E., 2003** - *A strong, long-track, Romanian tornado*, Atmospheric Research, 67-68, pp. 391-416.
10. **McDonald J., Mehta K. C., 2006,** - *A recommendation for an Enhanced Fujita Scale (EF-Scale)*, Wind Science and Enginering Center, Lubbock-USA.
11. **Povară R., 2004** - *Climatologie generală*,Fundatiei Romania de Maine, Bucharest.
12. **Snow J., 2009** - *Tornado: Global occurrence*, Encyclopædia Britannica Online.
13. **Teodorescu E., Andrei L., Manafu A., Ciucă A., Butnariu C., 2007** - *Managementul riscului de dezastru*, Bucharest.
14. **Wurman J., 2008** - *Doppler On Wheels*, Center for Severe Weather Research, Boulder USA
15. *****, 2015, Hurricanes and Climate** - *Hurricanes: Science and Society*, University of Rhode Island.