VAMA VECHE WATERSPOUTS OF 16 JULY, 2013

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ABSTRACT. – Vama Veche waterspouts of 16 july, 2013. As it is known, waterspouts generally occur in unstable thermodynamic stratification, light wind in the low troposphere and high Convective Available Potential Energy (CAPE) in the low layers. High values of CAPE are not necessary if there is heavy windshear in the first 3 km from ground level. Waterspouts can be produced by storm clouds with both supercell and non-supercell structure. The existence of the analyzed waterspout event was checked based on the general conditions for waterspouts and tornadoes occurrence, as proposed by Houze and Dotzek. The possibility that waterspouts occur was also verified using the Szilaghyi nomogram. In this context event, the synoptic, mesoscale environment and radar data highlighted the light wind in the lower troposphere, the occurrence of a low-level "hook" echo and of rotating structures in the radar reflectivity field, the presence of the radar signature of a mesocyclone and the existence of instability, sufficient moisture and wind shears in the lower boundary layer. Moreover, with the help of in-situ pictures, it was proved that the Vama Veche storm cloud did not preserve its mesocyclone stage and produced a series of waterspouts.

Key words: waterspout, Vama Veche, CAPE, mesocyclon, Szilaghyi nomogram

1. Introduction

Tornadoes are vortices which form from convective clouds and extend to the ground. Waterspouts are tornadoes over extended water surfaces (Dotzek et al., 2010). They appear as thin columns with the funnels sucking up water over mushroom-shaped water sprays. Waterspouts can vary in size from a few meters to more than a kilometer in height, and from a a few meters to hundreds of meters wide. These phenomena usually last up to fifteen minutes, and few last more than half an hour. Similar to tornadoes, waterspouts are often seen in groups. (http://library.thinkquest.org/C003603/english/tornadoes/waterspouts.shtml)

Normally, tornado formation depends on the following conditions (Houze,1993, Dotzek et al., 2010):

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- (potential) instability with dry and cold air masses above a boundary layer capped by a stable layer preventing premature release of the instability;
- a high level of moisture in the boundary layer leading to low cloud bases;
- strong vertical windshear (in particular for mesocyclonic thunderstorms);
- pre-existing boundary layer vertical vorticity (in particular for non mesocyclonic convection).

Waterspouts are a known hazard to both the marine and aviation communities (Szilagyi, 2009).Tornadoes and waterspouts can be frightening and threatening phenomena (Dotzek et al., 2010), attracting a lot of media-attention (Kuiper 2007). So, from a climatological point of view, a waterspout record is valuable as well, and these tornadoes should be a point of interest for European tornado research in the future (Dotzek, 2003). As forecasters have difficulty forecasting their initiation, conceptual models, based on radar, satellite and synoptic observations, have been developed. These have provided invaluable guidance for forecasters (Bell, 2009).

According to statistical database, the waterspouts in Europe are not abnormal events. Thus, 393 waterspouts per year are estimated to occur in Europe, based on the data reports from 28 countries (Dotzek, 2003).

Romania is a country that only recently began certifying the existence of tornadoes and waterspouts on its territory. Despite the fact that this kind of events was observed in the past by eyewitnesses, these were not recorded, due to lack of scientific evidence, and were considered as being anomalies. Along with the installation of Doppler radars in 2002, these phenomena became obvious in Romania as well.

The first tornado analyzed in Romania using Doppler radar was reported at Făcăeni village in 2002 (Lemon et al. 2003, Bell, 2010). In the last years an average of 10 tornadoes per year are observed and sometimes even video recorded in our country (Oprea and Bell, 2009, Bell, 2010). The European Severe Weather Database (ESWD) gives a total of 67 tornadoes and 7 waterspouts from 1901 to 2013, of which 13 tornadoes and 5 waterspouts were confirmed. Most of them have been recorded lately. The analyzed waterspout is one of the confirmed events as it appears in the ESWD. According to the statistics, in Romania a significant development of waterspouts occurs in late summer season with persisting warm weather.

The study of tornadoes in Romania is in an embrionary stage, therefore, there are only a few research studies in the domain that deal with them (Lemon et al., 2003, Pop et al., 2004, Bălteanu et al., 2004, Stan-Sion and Soci, 2005, Stan-Sion and Antonescu, 2006, Antonescu and Bell, 2007, Stan-Sion and Antonescu, 2007, Bell, 2009, Bell at al., 2009, Oprea and Bell, 2009, Antonescu et al., 2010, Bell, 2010, Buțiu and Nucuță, 2010), none of these being focused on waterspouts.

Waterspouts display five stages in their life cycle (Golden, 1974):

- The dark spot phase, when the water surface looks dark, as it is touched by the vortex or by the rotating air column;
- The spiral pattern phase, when bright and dark spirals occur beyond the dark spot;
- The spray ring phase when the cascade-like pulverizing ring occurs, formed around the dark spot, giving the impression of a central eye, like in hurricanes;
- The mature vortex phase, when the waterspout is at its peak intensity and is visible from the surface of the water to the cloudy area, appearing like a tubular funnel surrounded by vapors;
- The decay phase, occurring when the warm air flow within the vortex weakens and the whole water column collapses.

2. Data and methods

The existence of the analyzed waterspout event was checked based on the general conditions for waterspouts and tornadoes occurrence as proposed by Houze, 1993 and Dotzek et al, 2010. In order to achieve this, the synoptic and mesoscale environment data were analyzed, using ESTOFEX (European STOrm Forecast EXperiment) data, Doppler radar products and weather station data provide by Romanian National Meteorological Administration (ANM) and visible satellite imagery (www.sat24.com). ESTOFEX is the initiative of a group of European meteorologists to find out how severe convection can be forecast in (semi-) operational practice on the European continent (www.estofex.org). ESTOFEX issues daily forecasts with infrequent regional waterspout warnings (Keul et al 2009).

The possibility that waterspouts occur was also verified using the Szilaghyi nomogram. The waterspout Szilaghyi nomogram is currently used by The Meteorological Service of Canada, as well as the National Oceanic and Atmospheric Administration (US weather service), for the Great Lakes area (Szilagyi, 2009, Keul et al 2009).

3. Results

On 16 July 2013, between 11:00 and 12:00 UTC, a group of more waterspouts over the Black Sea, close to the shore of the Romania, near the Vama Veche village, were observed. The phenomenon slightly induced panic to the people present on the Vama Veche beach because of the wind gusts and of frightening features. The impact in the media was strong and the images were spectacular, as can be seen in the Figure 1.

Fig. 1. Photographs of waterspouts (photos source: ‚Ziua Veche' newspaper)

16 July, 2013 was an unsettled day, with temporarily cloudy sky and specific atmospheric hazards related to the summer storm clouds (rain showers, lightning and squall-like wind gusts).

Circulation was north-easterly at ground level, becoming northerly, at 850 hPa, and north-westerly, at 700 hPa (Fig. 2).

In the high troposphere a geopotential trough was lying over Romania, whereas circulation was south-westerly above Dobrudja (Fig. 3).

The ground-level map (Fig. 4, left) that renders the CAPE displayed values of hundreds J/kg over Dobrudja and western Black Sea areas. The ESTOFEX forecast for severe hazards events related to the convective processes (Fig. 4, right) mentioned a ‚level 1' probability for one or more severe phenomena in the area covering northern Bulgaria and southern Romania, meaning a 5% probability for one or more severe phenomena be reported within that area. The phenomena in question were mainly intense precipitation, hail and hard wind gusts. No such warning was made for the west of the Black Sea.

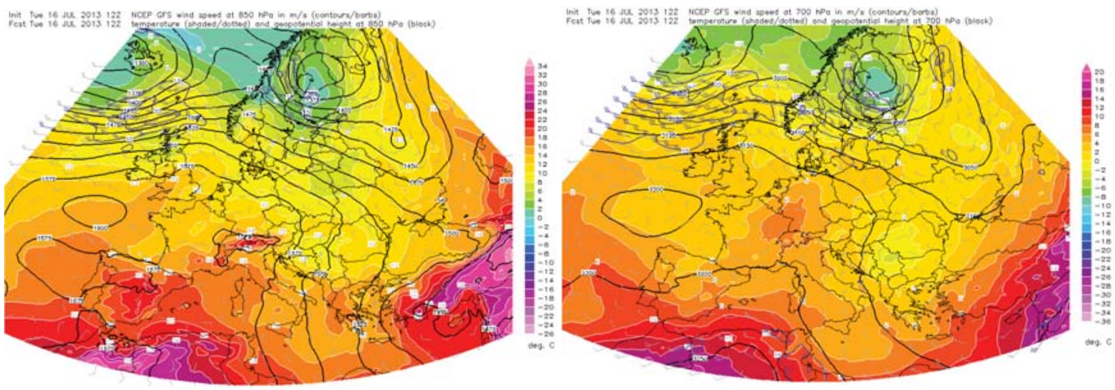

Fig. 2. ESTOFEX analysis at 850 hPa (left) and 700 hPa (right), on 16 July, 2013, 12:00 UTC

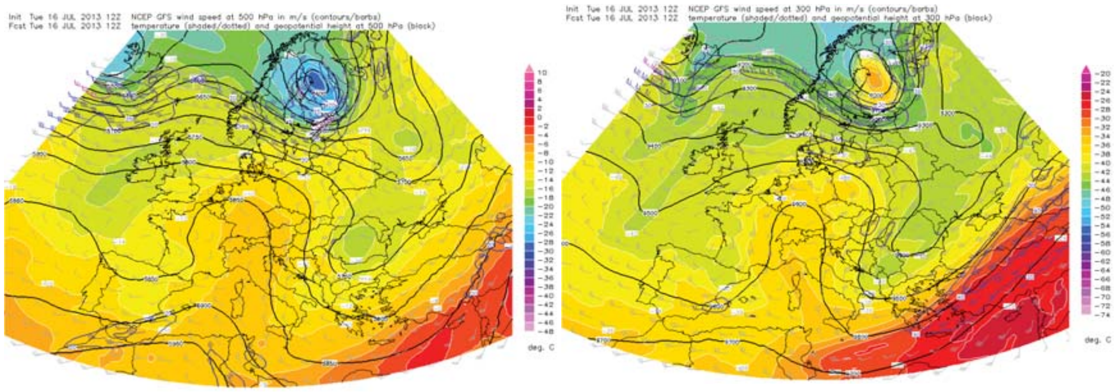

Fig. 3. ESTOFEX analysis at 500 hPa (left) and 300 hPa (right), on 16 July, 2013, 12:00 UTC

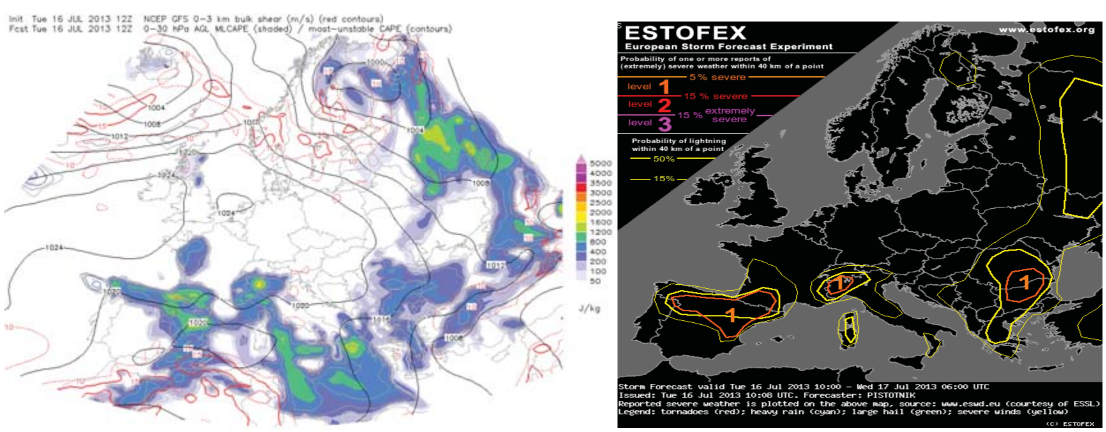

Fig. 4. ESTOFEX analysis of ground-level circulation and CAPE (left), and forecast for convective phenomena, on 16 July, 2013, 12:00 UTC (right)

Between 06:00 UTC and 12:00 UTC, geopotential decreased in the altitude. Under those circumstances, unstable air stratification was developed, with the additional contribution of the diurnal heating and height values of sea water temperature. At Mangalia weather station, the closest to Vama Veche location, the air temperature decreased from 25ºC at 12:00 Romania Daylight Time (RDT) to 18ºC at 15:00 RDT, with the sea water temperature remaining constant, at 23 – 24ºC, and the wind intensified around 14:30 RDT, from ENE, at a mean speed of 12 m/s and gusts of 19 m/s. At 16:00 RDT, the air temperature kept 18ºC and the wind died down to 1 m/s from W-NW.

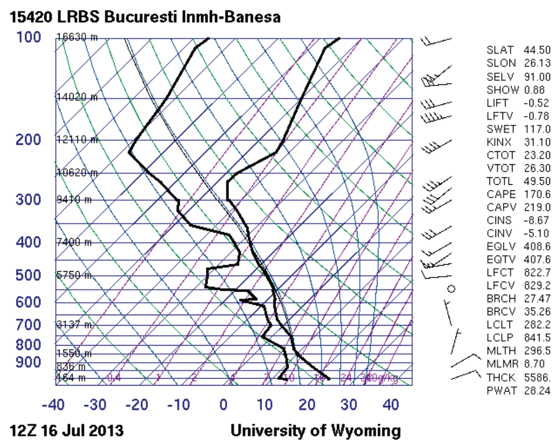

Fig.5. Bucharest upper air sounding on 16 July, 2013, 15:00 RDT (source: ANM)

The closest upper air sounding, performed at Bucharest, showed a rather small CAPE and also a small distance between the lifting condensation level (cloud base) and the Level of Free Convection (LFC) (Fig. 5). Thus, once the updraft of the air particle is initiated, that particle reaches more easier the LFC. From that level to the Equilibrium Level (EL), the air particle is warming than the surrounding air and the upward motion will continue naturally and accelerated.

On the radar image showing the echoes height (Fig. 6, top left) as well as on other radar products, a mesocyclone, shaped as a small yellow circle, was detected. This indicates the presence of a convective cell with a high rotational potential.

The convective cloud development did not reach heights greater than 6000 – 8000 m a.s.l. Nevertheless, a high reflectivity of up to 69 dB was recorded between 14:03 and 14:45 RDT, probably because of the presence of hail and VIL (Vertically Integrated Liquid water) up to 54 km/m^2. Thus, the first condition for waterspouts formation, the one connected to instability, was fulfilled.

As regards the second condition, related to the moisture within the boundary layer, it can be mentioned that in a landwards north-eastern circulation with a reasonably high water temperature, the moisture contribution was sufficient for the occurrence of clouds with a low base.

Examining the air circulation, it can be noticed that the wind shear was quite important, more important than assessed by the models' runs on that day. The variation of the wind speed and direction with height (wind shear) can be seen in (Fig. 6, top right). The VWP (VAD Wind Profile) product displays as time series the wind direction and speed at various time intervals (every 6 minutes – the time it takes for a scan to complete), at various altitudes, resembling to the 15:00 RDT sounding at Bucharest (see Figure 5). These two products prove that there was almost continuous anticlockwise wind share in the whole air column (colder air advection). Thus in the first 6 km from the ground, the wind rotated anticlockwise by about 120º.

It is known that wind shear is an important condition in organizing convection and implicitly in the life cycle of the convective cells. A CAPE of several hundred J/kg and severe wind shear could be sufficient to generate tornadic storms.

The combined wind shear radar product (wind shear in the azimuth and in the distance) also points large values at the time when the phenomena climaxed (Fig. 6, down left). Thus, the condition connected to the existence of severe wind shear for waterspouts to occur was also fulfilled.

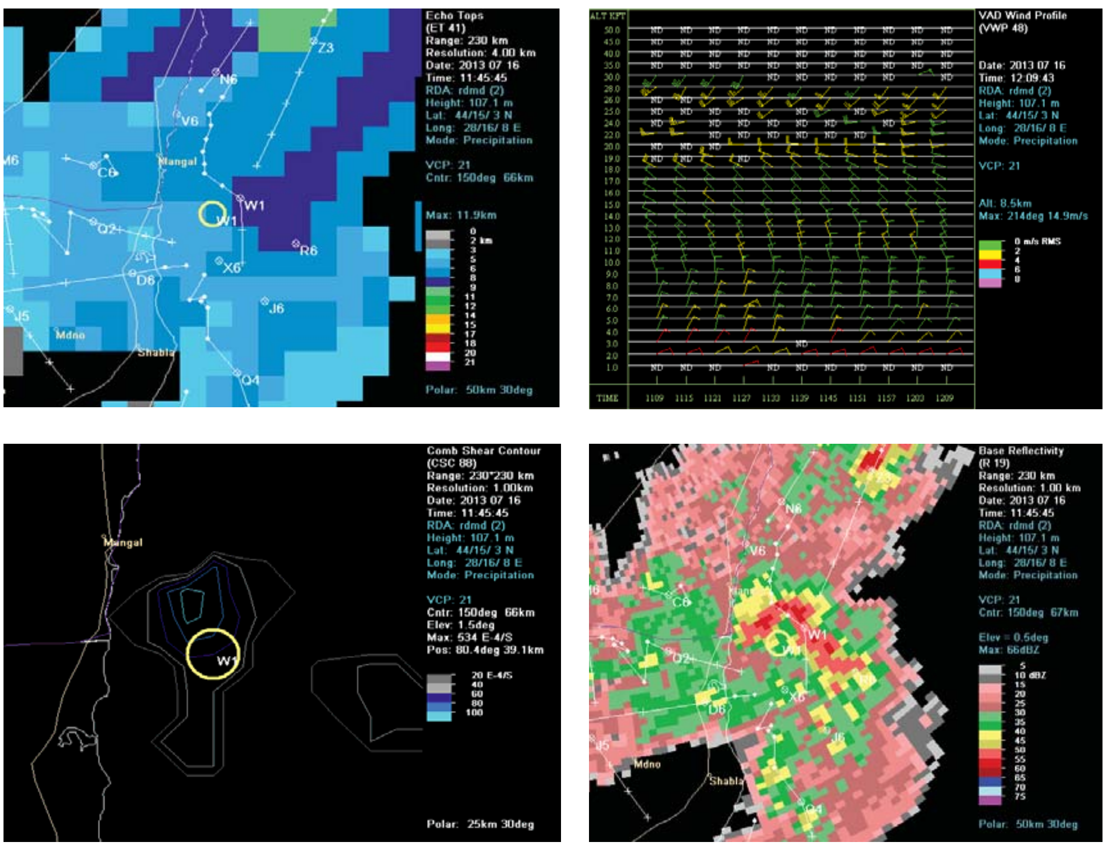

Fig.6. Different types of products provided by the nearest Doppler radar (i.e. Medgidia Doppler radar) on 16 July, 2013: radar echoes height (top, left), VWP (top, right), combined windshare (down, left) and radar reflectivity (down, right) (source: ANM)

Watching the radar reflectivity image (Fig. 6, down right) it can be seen a “hook”-type structure, which suggests where the rotation took place and a Bounded Weak Echo Region (BEWR) within the “hook”, which is the updraft source. In this case, the stronger the updraft, the more intense the convective phenomena.

The presence of the “hook echo” beside the mesocyclone signature is an indicator of the existence of low level vorticity, meaning that the fourth condition necessary for waterspouts occurence was also fulfilled.

The image of the Doppler speeds (Fig. 7, left) shows clearly enough that there was a rotational structure.

The rotation motion is much more obvious in Fig. 7 (right image), which shows the field of the Doppler velocities relative to the storm clouds (Storm Relative Velocity) (i.e. a radar product which renders the result of subtracting the motion speed of the cloud system as a whole from the total speeds field, which better highlights the individual motions of the convective cells).

As source of dynamic updraft, the linear convergence of the breeze front would have sufficed to initiate the updraft, on condition that the lifting air mass remained warmer than the surrounding air up to the level of free convection, after which the motion would have gone on naturally to the level of equilibrium. There the temperature of the lifting air mass would have become equal to that of the surrounding air and the updraft had continued in deceleration until halting.

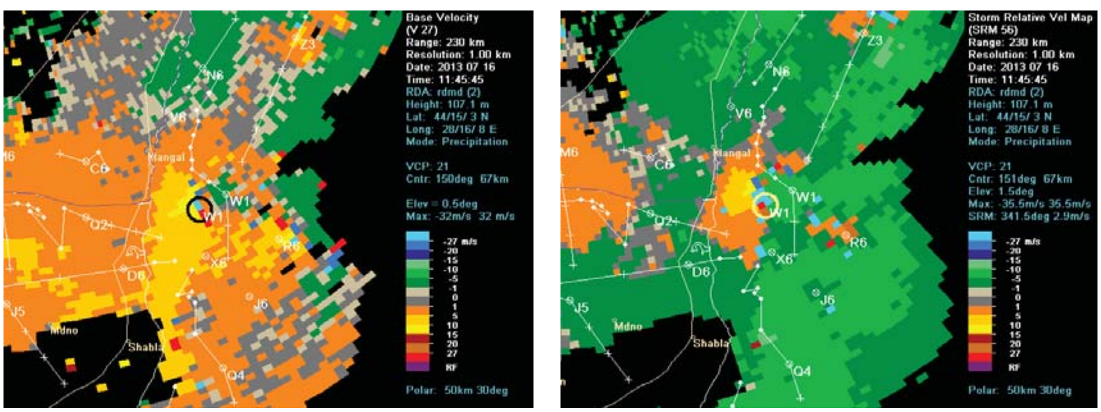

Fig. 7 Doppler speed (left) and relative storm speed (right) on 16 July, 2013, 11:45 UTC (source: ANM)

In the upper air, on sounding displayed in Fig. 5, the Lifted Index (LI) is slightly negative (-0.5ºC). LI is an index of the updraft potential of an air particle and is computed by computing the difference between the temperature of the surrounding air at the level of 500 hPa and the temperature of the air particle experiencing updraft at the same level.

Satellite images also captured the phenomena that took place at sea in Vama Veche coastal area, along with the belonging convective cells, as can be seen in Fig. 8.

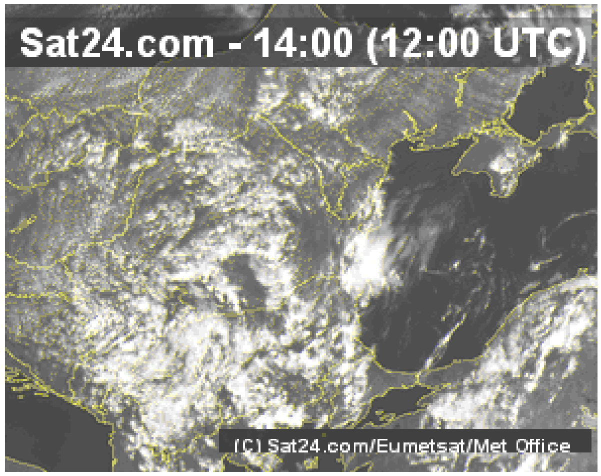

Fig. 8. Satellite image on 16 July, 2013, 12:00 UTC (source: http://www.sat24.com/)

To verify the possibility of waterspouts occurrence after the Szilagyi nomogram, the following were taken into account:

- the top of the convective cell was assessed at 7800 m.a.s.l. and the cloud base height at 800 m.a.s.l., indicated a vertical cloud length of 7000 m (22 965 ft.) (Fig.9);
- the sea water temperature was about 24ºC and the temperature at the level of 850 hPa about 11ºC, i.e. a difference of 13ºC.

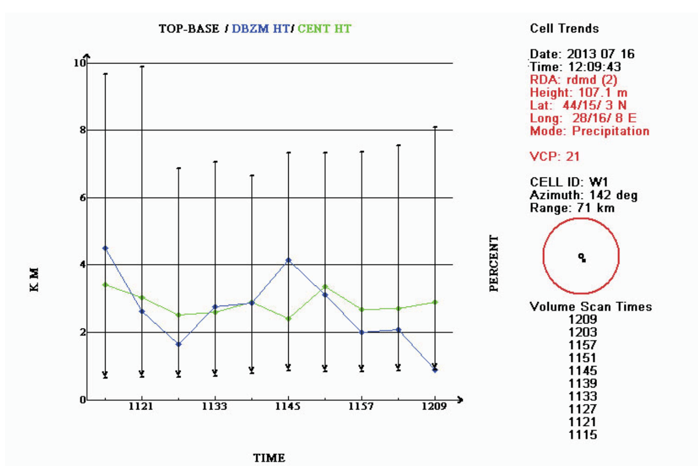

Fig. 9. Cell trends used to determine the vertical length of cloud echoes (source: ANM)

The intersection point of those two parameter's differences was between the two red lines, very close to the blue subzone figured on the nomogram (Fig. 10). Therefore, it can mention that, the occurrence of the Romanian waterspouts could be anticipated with reasonable likelihood by using the nomogram.

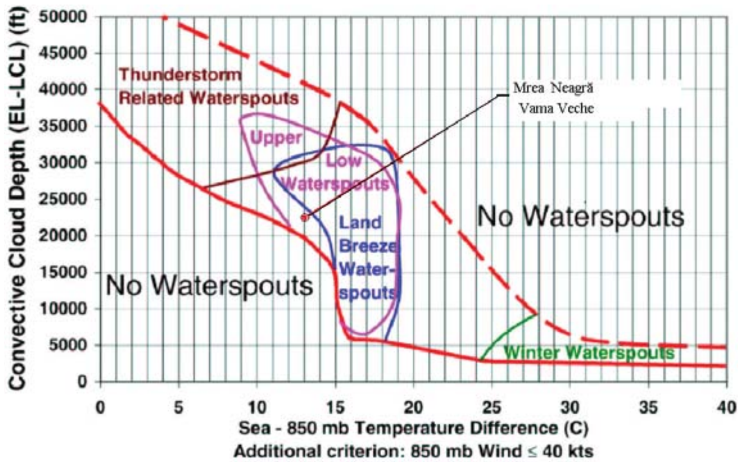

Fig. 10. Forecast of Vama Veche waterspouts using the Szilagyi nomogram

Conclusions and discussions

The displayed situation demanded careful monitoring; in fact two warnings for hazardous phenomena were issued for the coastal area of Dobrudja at 12:50 RDT, mentioning possible precipitation amounts exceeding 25-35 mm, thunder strikes, hail and squall-like wind gusts.

As proposed by Houze and Dotzek, the conditions for tornado and waterspout formation, constitute a general frame, but in the operational activity it's difficult to ascertain their simultaneous occurrence.

The imagery provided by the Doppler radar show a strong rotational mesocyclonic structures.

In that situation in which the Medgidia Doppler radar has detected a Tornadic Vortex Signature (TVS), it would have been certain that an amplification of the rotational motion occurred through the expansion of the vertical vorticity preexisting within the updraft, so as to lead to the occurrence of a waterspout. The expansion of the vertical vorticity does not always occur, so that many convective cells preserve their mesocyclone stage.

At more than 60 km, which is the distance from Medgidia to the location of the convective cell, the width of the radar beam with a 1º aperture is approximately 1 km, whereas the diameter of the waterspots, as estimated by the eye witnesses, was only several tens of meters. It was, thus, less likely for two adjoining radar beams to spot a couplet of high Doppler speeds, towards and from the radar respectively, so as to ascertain the TVS, according to the algorithm used by the radar equipment. Nevertheless, those two beams identified the general rotational motion in the area, much more spatially expanded, and marked by the signature of a mesocyclone.

Applying the Szilagyi methodology for the analyzed event, it can say that the occurrence of the Romanian waterspouts could be anticipated with reasonable likelihood.

On the other hand, without the eye witnesses, meteorologists would have considered that the convective cell evolved only to the stage of a mesocyclone.

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