The application of selected methods for detection of tornadoes in Poland (case studies)

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I. INTRODUCTION

Every year over the area of Poland we record several dozens of events which the media and the public tend to call tornadoes. However, the majority of such occurrences are connected with strong winds produced by e.g. downburst, and only very few events are actually the consequences of a real tornado. Unfortunately, due to the lack of basic emergency warning system, even those few events happen to be highly destructive and pose threat to human life or well-being. This is mainly the outcome of selective monitoring of tornadoes performed in our country and no practical application of radars to detect them. The fact that no multi-faceted research on this topic has been carried out makes it difficult to specify potential conditions conducive to occurrence of tornadoes in this region of Europe. As a result, implementation operations aimed at safety improvement have been abandoned.

In Poland, the detection of whirlwinds (including tornadoes) is difficult due to their local specifics. The Polish observation network is limited to slightly over 60 synoptic stations. Thus far, only one of them recorded the occurrence of such rotational phenomena. This was landspout, which appeared on 21.08.2004 above the Regional Hydrological and Meteorological Station in Opole (*www.imgw.pl*).

Furthermore, the aerologic surveys over the Polish territory are performed on three stations (Łeba, Legionowo and Wrocław), with surveying frequency of two times per day (00 UTC, 12 UTC). The radar images are gathered by Institute of Meteorology and Water Management (IMGW), which uses the POLRAD network, which was fully released for use only in 2004. It is composed of 8 Doppler radars: Gdańsk, Świdwin, Poznań, Legionowo, Pastewnik, Ramża, Brzuchania and Rzeszów (fig. 1).

The study analyses only one fully confirmed instance of a tornadoes (14.07.2012). It was selected on the foundation of certain assumptions. First, the phenomenon created up to 200 km from the aerologic stations in time within 6h following or 3h or less before the survey was taken into consideration (Potvin and others 2010). Second, due to the range of the radar, the selected tornado was within 125 km of it (Moszkowicz, Tuszyńska 2006).

The purpose of this paper is then to specify potential meteorological conditions characteristic for these days when dangerous tornadoes occur in Poland, as well as to evaluate the possibility to detect them by means of available methods and devices.

The article presents the course of severe winds and wirlwinds in Poland and analyzed in detail the case of tornadoes from July 14, 2012.

Based on ESWD reports, a set of tornado-type occurrences was selected. Several radar products were analysed in time intervals of 10 minutes. The following parameters were considered: maximum values of reflectivity, vertical wind profile, as well as turbulences, echo height. Based on radar products the altitude of storm cloud tops was defined.

The data concerning radar products comes from the Institute of Meteorology and Water Management (IMGW). The vertical aerological soundings were acquired from the website: *http://weather.uwyo.edu/upperair/sounding.html*.

Additionally, the satellite images and synoptic maps were used (from *www.sat24.com* and *www.pogodynka.pl*). In order to analyse thermodynamic instability, convective indices were used.

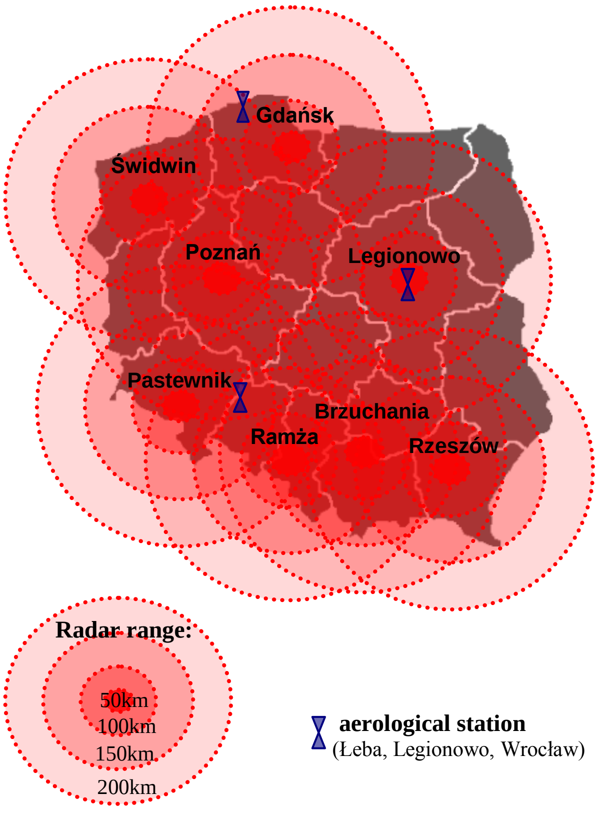

FIG. 1: Polish radar network POLRAD (own study).

II. PRESENTATION OF RESEARCH

During the years 2000-2012, 1036 severe winds and as many as 301 whirlwinds were created over Poland (fig. 2). Over multiple years, the growth of the frequency of severe winds appearance from year to year is noticeable. However, this is related mainly to the development of the monitoring of such phenomena in recent years and improved information flow. Almost 290 appeared in 2012 and over 250 in 2011. In the case of whirlwinds, such a clear trend is not visible. The most such phenomena were recorded in 2006 (52 cases). On average during these years, approximately 23 whirlwinds were created per year.

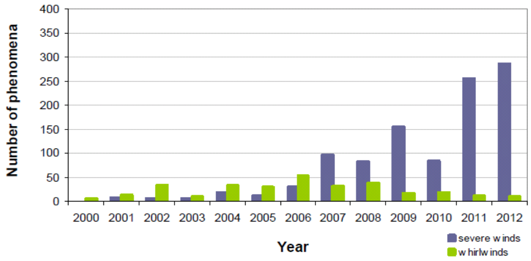

FIG. 2: Long-term course of severe winds and whirlwinds in Poland – period 2000–2012 (own study based on ESWD reports).

During the year (fig. 3), severe winds appeared most frequently in July (almost 335 cases) and August (almost 190 cases). These months also recorded the most whirlswinds – adequately 79 (in July) and 71 (in August). Most such phenomena appear during the summer and are related to convectional storms or storms accompanying the passing of the cool front.

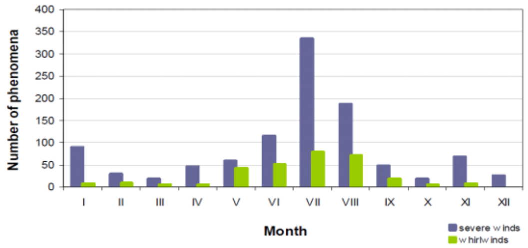

FIG. 3: Annual course of severe winds and whirlwinds in Poland – period 2000–2012 (own study based on ESWD reports).

Severe winds and whirlwinds usually appeared in the afternoon, i.e between 12:00 and 6:00 pm UTC (fig. 4). The most severe winds (over 100 cases) formed at about 12:00 UTC. The least such phenomena appeared at night, between 1:00 and 9:00 am UTC. 81 severe winds have been recorded at midnight. However, most of these instances are phenomena included in this group due to their unconfirmed hour of formation. Furthermore, the examined multiyear period saw the appearance of 46 whirlwinds of approximately at 4:00 pm UTC and 37 instances of approximately at 3:00 pm UTC.

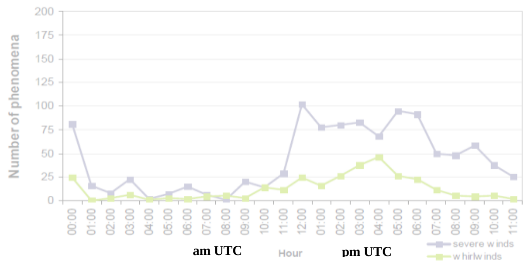

FIG. 4: 24h course of severe winds and whirlwinds in Poland – period 2000–2012 (own study based on ESWD reports)

The largest numbers of severe winds appeared within the following voivodeships: *Mazowieckie* (124 cases) and *Wielkopolskie* (121 cases). The least, only 17 instances, appeared in *Opolskie*. Whirlwinds most often visited *Zachodniopomorskie* (30 cases), *Pomorskie* (29 cases) and *Warmińsko-Mazurskie* (28 cases). Their rarest formations were in *Dolnośląskie* and *Lubuskie*, which saw only 9 instances each (fig. 5).

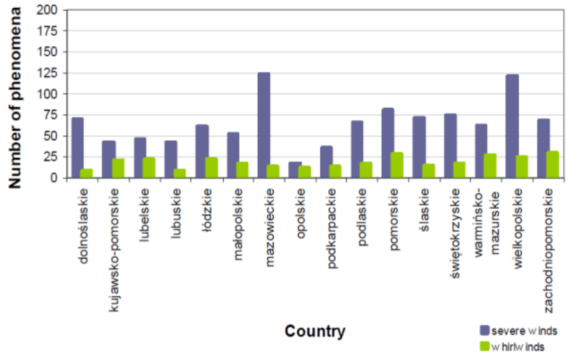

FIG. 5: Severe winds and whirlwinds in Poland by voivodeship – period 2000–2012 (own study based on ESWD reports).

Based on the spatial arrangement of severe winds and whirlwinds in Poland (only years 2000-2010) can not clearly identify the areas most frequently haunted by these phenomena. However, we can distinguish two zones with increased activity of severe winds (south-western and southern Poland). In the case of whirlwinds, you can set a narrow coastal lane and the area south of the country (fig. 6).

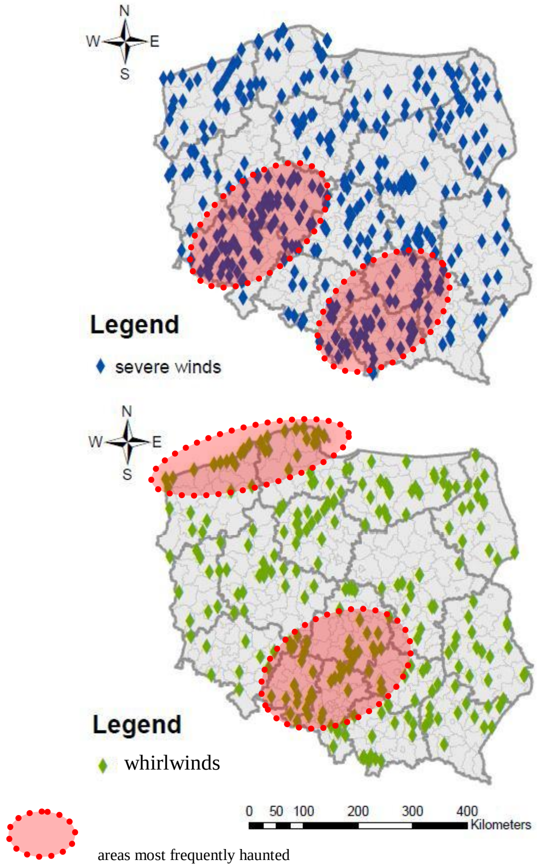

FIG. 6: Spatial arrangement of severe winds and whirlwinds in Poland – period 2000–2012 (own study based on ESWD reports).

On 14 July 2012 between 2:45 and 4:00 pm UTC, there were tornadoes passing over the *Kujawsko-Pomorskie* and *Pomorskie* voivodeships. On the basis of the reports of eyewitnesses and analysis of the destruction zone, this was not a tornado outbreak phenomenon, since only tree funnel clouds were observed. Although they were formed from the storm cell, which was associated with the passing of the cool front (fig. 7), there was a small so-called QLCS (Quasi-Linear Convective System) formed on the outskirts of this front (around 12:30 pm UTC), which covered a belt of average length of approximately 200 km and width of approximately 60 km (fig. 8).

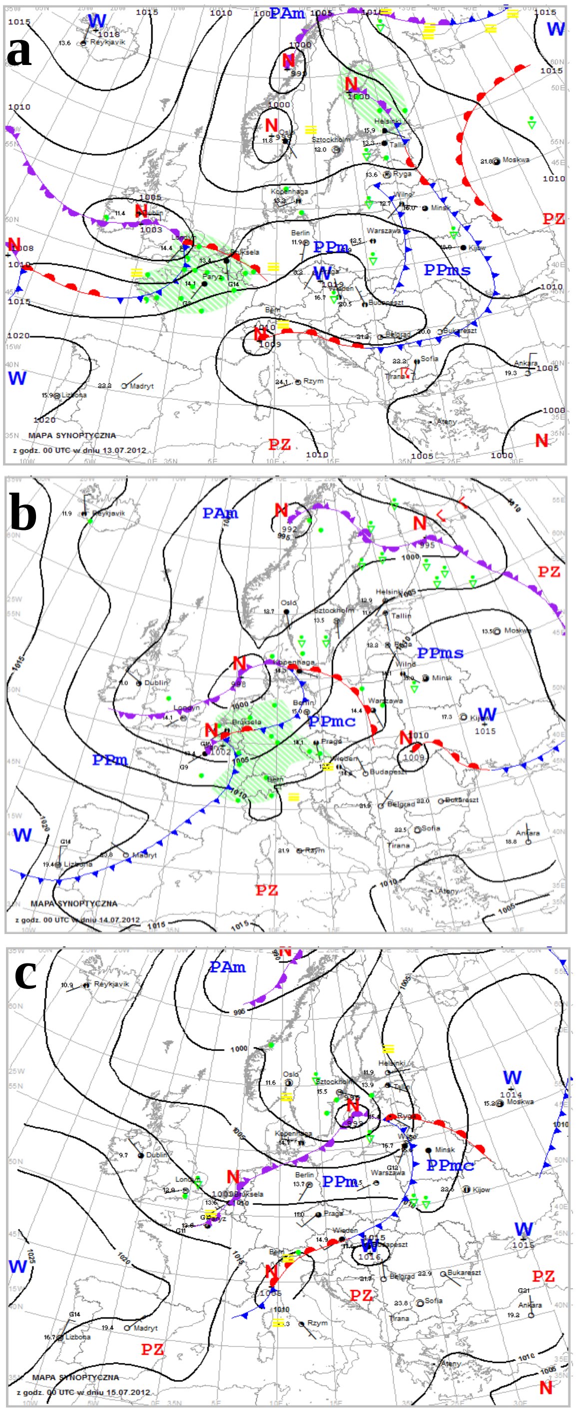

FIG. 7: Meteorological situation for Europe at 00:00 UTC on: a) 13.07.2012 ; b) 14.07.2012 ; c) 15.07.2012 (*www.pogodynka.pl*).

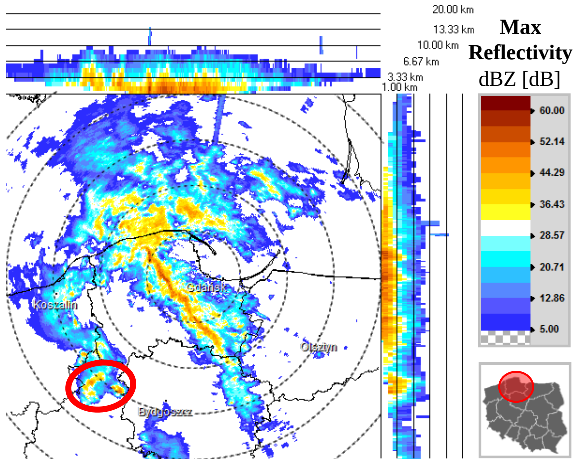

FIG. 8: QLCS in 14.07.2012 at 1:30 pm UTC with the marked storm cell (*red circle*), which at a later stage of development generate tornadoes (own study based on radar product – IMGW).

At July 13, 2012, masses of polar maritime air occurred over the central part of Europe. Poland was under the influence of low pressure multi-centre from over Scandinavia, and one of its centers appeared in the north-western Germany and the southern part of the North Sea. During the night from the 13th to the 14th of July, the west and north of Poland noted the influence of shallow bays associated with low pressure center, which moved up from the North Sea over Denmark. Warm front belonging to the low pressure moved from west to central districts. He divided the two polar maritime air masses: inflowing from the west warm and wet from the old (in the east). The low pressure was related to active and fast-moving waving cold front, that moved in from the west to the center. In the middle and upper troposphere was marked by a jet-strem (about 50 m/s). Therefore phenomenon of storm occurring in the low pressures center and the front area were quite violent. Analysing series of satellite images from this day, it is possible to see that the storm cell from which the tornadoes were formed began to develop at approximately 2:00 pm UTC (fig. 9).

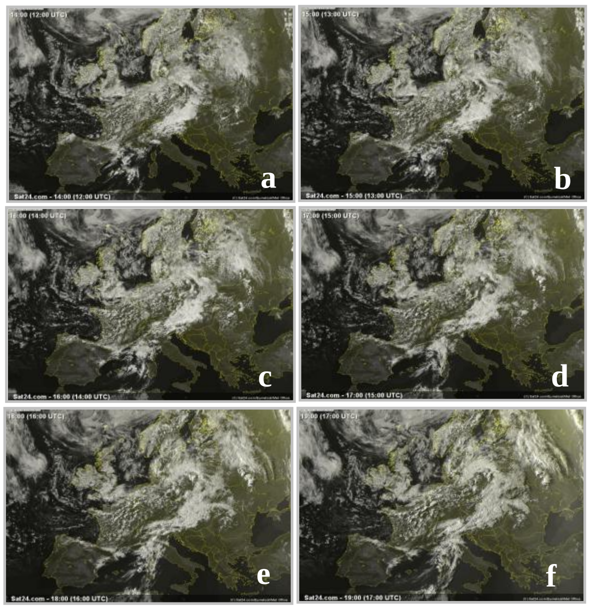

FIG. 9: Satellite images in visible to Europe in 14.07.2012 at: a) 12:00 UTC; b) 1:00 pm UTC; c) 2:00 pm UTC; d) 3:00 pm UTC; e) 4:00 pm UTC; f) 5:00 pm UTC (source: *www.sat24.com*).

It can also confirm radar images. Rainfall associated with storm cells have become extremely intense about 2:50 pm UTC, when the locally recorded the maximum value of reflectivity, up to 57.15 dB (fig. 10).

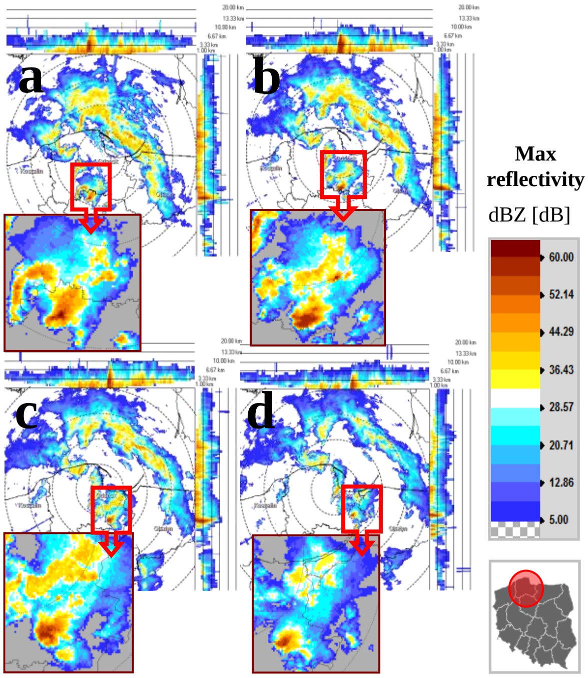

FIG. 10: Maximum values of reflectivity in 14.07.2012 at: a) 2:50 pm UTC b) 3:20 pm UTC c) 3:40 pm UTC d) 4:00 pm UTC (own study based on radar product – IMGW).

One of the radar products (so-called *Echo Height*) allowed to establish the maximum height of the cloud tops of the storm formation, from which the tornadoes were formed. At 3:00 pm UTC, parts of the cloud accumulated to the height up to 12.51 km (fig. 11).

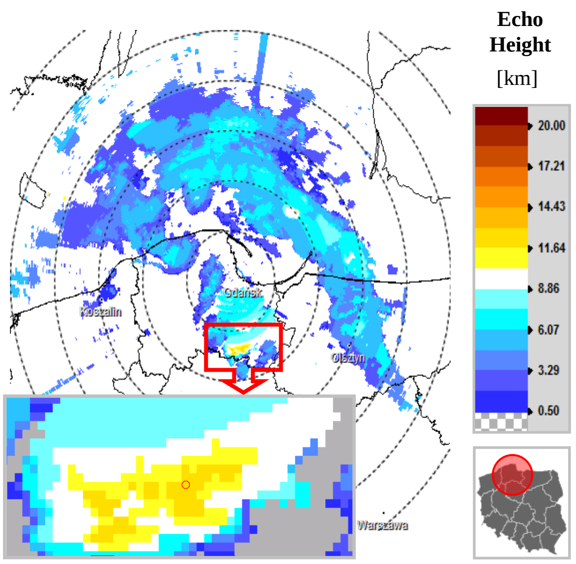

FIG. 11: Echo Height in 14.07.2012 at 3:20 pm UTC with marked (*red circle*) the highest value (own study based on radar product – IMGW).

Based on radar product (*Vertical wind profile*), direction and wind speed with height were analyzed (fig. 12). Furthermore, using radar product (so-called *LTB*) maximum turbulence also evaluated (up to 6,5 m/s).

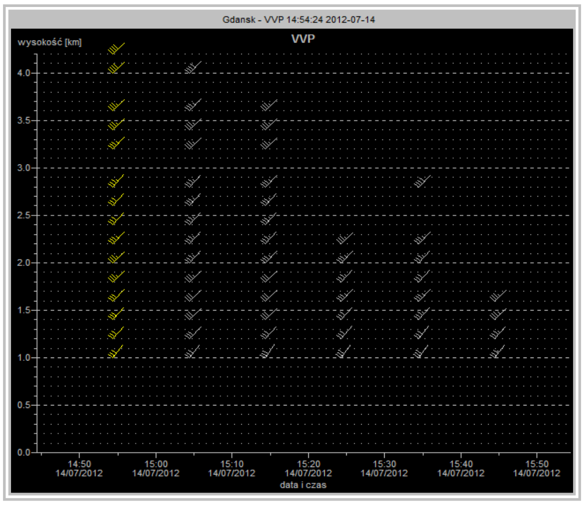

FIG. 12: Vertical wind profile in 14.07.2012 from 2:50 to 3:50 pm UTC (own study based on radar product – IMGW).

The station in Łeba is located at 6 m above sea level. During the aerologic survey, the air temperature was 17,8°C, while the dew point temperature was 16,1 °C. The wind speed was 4,1 m/s from the SSW direction. The atmospheric pressure was 1000 hPa.

14th July 2012 sbCAPE and muCAPE indicators for 12:00 UTC amounted to 800 J/kg. The CAPE value for the averaged particles from lower 500 m did not exceed 110 J/kg (fig. 13a). Although the indexes showed a slight instability in the atmosphere, there was create a 3 tornadoes. They were correlated with the storm cell moving to the right. Analyzing the value of SRH (0-3km) which was 101 m^2/s^2 can say that this day prevailed pretty minimal conditions for development of supercells. However, according to some authors, a high risk formation of tornadoes is appearing at the threshold of SRH (0-1km) equal 75 m^2/s^2, and for the analyzed case of July 14, 2012 the value of SRH (0-1km) was similar and was 74 m^2/s^2 (Thompson and Mead 2006). Also calculated Effective SRH equals 22 m^2/s^2. EHI indices were lower than the one which shows little potential for convective and mesocyclones processes. The value of CIN (0 J/kg) suggests that the atmosphere this day was a little stable, and convective processes are only possible with the average value of CAPE. Not a high value BRN shear (28 m^2/s^2) was not conducive to the formation of mesocyclones in cells and their conversion into supercell, which also confirms the value of STP which was then 0. The calculated value of the SCP was close to zero (0,2) which indicates a low probability of formation of mesocyclone storms that day. Moreover, by analyzing the wind blowing in the supercell at 500 hPa (500 hPa SR wind), it can be concluded that the calculated speed (8,1 m/s) could support the development of supercell tornadoes. However, in case of the wind blowing into the supercell on level 300 hPa (300 hPa SR wind), it is possible to regard, that if it developed, it was a HP supercell (11,9 m/sec). In addition, the DLS value (0-6 km shear) indicates an increasing probability of severe form of multicellular systems (15 m/s). What's more, DLS value (0-6 km shear) is attesting to the growing probability of creating ominous multicellular layouts (15 m/sec). Wind shear from bottom kilometres of the troposphere (0-3 km shear) proves that on that day minimum conditions appeared for the development of stormy arrangements with the developed squally front (10,4 m/sec.).

The station in Legionowo is located at 96 m above sea level. During the aerologic survey, the air temperature was 23,4 °C, while the dew point temperature was 11,4 °C. The wind speed was 3,1 m/s from the SSW direction. The atmospheric pressure was 994 hPa.

14th July 2012 sbCAPE and muCAPE indicators for 12:00 UTC amounted to 30 J/kg. The CAPE value for the averaged particles from lower 500 m did not exceed 0 J/kg (fig. 13b). On the basis of SRH (0-3 km) from this station which was 173 m^2/s^2 it can be concluded that day prevailed moderately favorable conditions for the development of supercells. What confirms the value of SRH (0-1 km) equal 101 m^2/s^2. However, the index Effective SRH was 0 m^2/s^2. EHI indicators at this station were also less than 1, indicating a low potential for convective and mesocyclone processes. Also in this case the value of CIN (0 J/kg) suggests that the atmosphere that day was poorly stable. However, the high value of BRN shear (even 68 m^2/s^2) favored the formation of mesocyclones in the cells and their transformation into a supercell. Do not support this value of STP and SCP, which then amounted to 0. This indicates a low probability of formation of a mesocyclone storm that day. Furthermore, by analyzing the wind blowing in the supercell at 500 hPa (500 hPa SR wind), it can be concluded that the calculated speed (12,8 m/s) could favor the development of supercell tornadoes. However, in the case of winds in supercell at 300 hPa (300 hPa SR wind), it can be concluded that if it developed, it was a LP supercell (40,1 m/s). DLS value (0-6 km shear) provides a very high probability of formation of a supercell (24,4 m/s). Wind shear in the lower troposphere kilometers (0-3 km shear) also shows that on that day there were minimal conditions for the development of storm systems, with a developed squall front (12,1 m/s).

The station in Kaliningrad is located at 21 m above sea level. During the aerologic survey, the air temperature was 20,4 °C, while the dew point temperature was 13,4 °C. The wind speed was 2,1 m/s from the SSE direction. The atmospheric pressure was 1002 hPa.

In the case of indicators sbCAPE and muCAPE for 12:00 UTC of this station they were at 280 J/kg and 310 J/kg. CAPE calculated for the averaged particle of the lower 500 m was equal to 200 J/kg (fig. 13c). SRH (0-3km) index was 147 m^2/s^2, so it can be concluded that conditions prevailed for the development of supercells. Tornadoes have a chance to create, because the index SRH (0-1 km) was 80m^2/s^2. Effective SRH was equal to 12.1 m^2/s^2. EHI indices were close to 0, and provide a low potential for convective and mesocyclone processes. CIN values also confirm that the atmosphere that day was a little stable, and convective processes are only possible with the average value of CAPE. However, even at this station appeared high value BRN shear (40 m^2/s^2), which favored the formation of mesocyclones in the cells and their transformation into a supercell. STP and SCP were close to 0, which shows little chances of the occurrence of mesocyclone storms. By analyzing the wind blowing in the supercell at 500 hPa it can be concluded that speed (8,8 m/s) favor the development of supercell tornadoes. However, in the case of winds in supercell at 300 hPa it may be considered that if it developed, it was a HP supercell (11,9 m/s). DLS indicates an increasing probability of severe form of multicellular systems (16,6 m/s). Wind shear in the lower troposphere kilometers shows that on that day there were minimal conditions for the growth of storm systems with developed squall front (13,4 m/s).

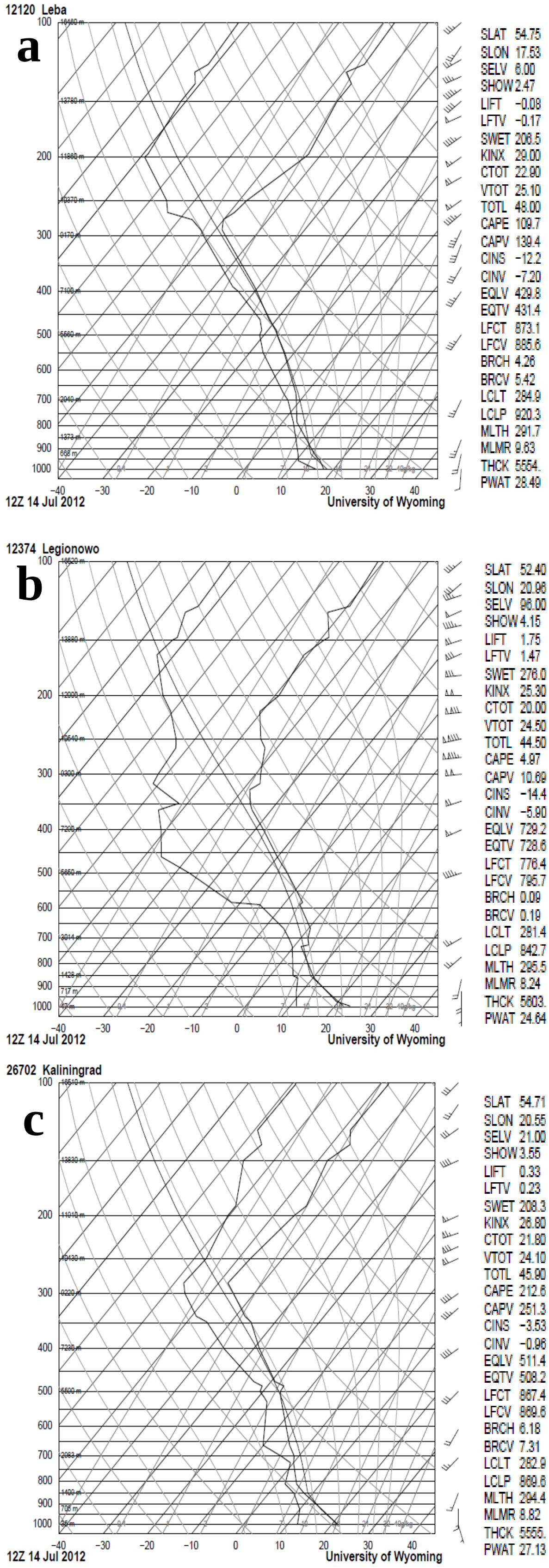

FIG. 13: Atmospheric soundings in 14.07.2012 at 12:00 UTC for a) Łeba ; b) Legionowo ; c) Kaliningrad (source: http://weather.uwyo.edu/upperair/sounding.html)

Detailed values calculated on the basis of atmospheric soundings from the station in Łeba, Legionowo and Kaliningrad shown in table 1.

TABLE I: Convection parameters from atmospheric soundings on July 14, 2012 at 12:00 UTC.

INDICATORS	STATION		
	Łeba	**Legionowo**	**Kaliningrad**
sb CAPE	800 J/kg	30 J/kg	280 J/kg
muCAPE	800 J/kg	30 J/kg	310 J/kg
mlCAPE (500m)	110 J/kg	0 J/kg	200 J/kg
sbCIN	0 J/kg	0 J/kg	-40 J/kg
muCIN	0 J/kg	0 J/kg	-20 J/kg
mlCIN	-10 J/kg	0 J/kg	0 J/kg
ICAPE	110 kJ/m^2	0 kJ/m^2	170 kJ/m^2
ICIN	0 kJ/m^2	0 kJ/m^2	0 kJ/m^2
sbLI	-2,32 °C	0,75 °C	0,14 °C
muLI	-2,32 °C	0,75 °C	-0,06 °C
mlLI	0,2 °C	2,1 °C	0,85 °C
sbLCL	220 m	1500 m	890 m
muLCL	220 m	1500 m	1020 m
mlLCL	690 m	1400 m	1190 m
sbLFC	520	1500	1140
muLFC	520	1500	1120
mlLFC	1140	2200	1240
sbEL	9720	2650	6990
muEL	9720	2650	7170
mlEL	4890	2600	5240
sb 0-3_CAPE	210	30	140
mu 0-3_CAPE	210	30	140
ml 0-3_CAPE	70	0	110
LR 0-1 km AGL	7,2 °C/km	11,1 °C/km	8,5 °C/km
LR 2-4 km AGL	5,2 °C/km	4,8 °C/km	5,4 °C/km
Precipitable water	28,0 mm	24,3 mm	26,8 mm
K Index	29,0	25,3	26,8
DCAPE	180 J/kg	440 J/kg	290 J/kg
0-6 km shear (DLS)	15,0 m/s	24,4 m/s	16,6 m/s
0-3 km shear	10,4 m/s	12,1 m/s	13,4 m/s
0-2 km shear	9,1 m/s	10,5 m/s	9,9 m/s
0-1 km shear	7,4 m/s	7,4 m/s	6,3 m/s
3-6 km shear	5,7 m/s	12,3 m/s	3,5 m/s
0-8 km shear	11,6 m/s	29,1 m/s	19,0 m/s
1-8 km shear	4,9 m/s	26,7 m/s	15,0 m/s
BRN shear	28 m^2/s^2	68 m^2/s^2	40 m^2/s^2
SRH (0-3 km)	101 m^2/s^2	173 m^2/s^2	147 m^2/s^2
SRH (0-1 km)	74 m^2/s^2	101 m^2/s^2	80 m^2/s^2
Effective shear	12,6 m/s	0,0 m/s	12,1 m/s
500 hPa SR wind	8,1 m/s	12,8 m/s	8,8 m/s
300 hPa SR wind	11,9 m/s	40,1 m/s	11,9 m/s
SCP new	0,2 (RM) 0,1 (LM)	0,0 (RM) 0,0 (LM)	0,2 (RM) 0,0 (LM)
SCP old	0,6 (RM) 0,3 (LM)	0,1 (RM) 0,0 (LM)	0,5 (RM) 0,2 (LM)
STP new	0,0 (RM) 0,0 (LM)	0,0 (RM) 0,0 (LM)	0,0 (RM) 0,0 (LM)
STP old	0,3 (RM) 0,1 (LM)	0,0 (RM) 0,0 (LM)	0,1 (RM) 0,0 (LM)
EHI 1	0,4 (RM) 0,1 (LM)	0,0 (RM) 0,0 (LM)	0,1 (RM) 0,0 (LM)
EHI 3	0,5 (RM) 0,2 (LM)	0,0 (RM) 0,0 (LM)	0,2 (RM) 0,1 (LM)

I. RESULTS AND CONCLUSIONS

In order to determine the potential meteorological conditions, which most often favour the formation of tornadoes over Poland, with high probability, it is necessary to perform detailed analyses of all or at least most of these instances (case studies). Thus far, such multi-aspect research has not been conducted. The first attempts were made on the basis of 30 tornadoes from the years 2000-2010 (Walczakiewicz, Ostrowski, Surowiecki 2011). The circles of scientific contemplations usually contained individual instances for example: 20.07.2007 (Parfiniewicz 2009). 15-16.08.2008 (Lorenc and others 2008). The conclusions formed thus far concern the studies of the general phenomena of whirlwinds (Lorenc 2012). Unfortunately, due to the lack of professional methods of their monitoring, we do not even know what percent of this is composed by tornadoes, landspouts or waterspouts. Furthermore, there is also a shortage of fundamental information on the number of storms during the year, which generate such phenomena. The types of formations from which tornadoes are usually formed have also not been classified. This study confirms the results of the research acquired by other authors. Among the conditions favouring the formation of tornadoes on 14.07.2012 were the elevated vertical wind leaps and somewhat reduced condensation level. Although CAPE (Convective available potential energy) reached rather moderate values, the lower troposphere was very humidity. (Walczakiewicz, Ostrowski, Surowiecki 2011). The appearance of such dangerous phenomena was associated with the passing of the cool atmospheric front (Lorenc 2012).

IV. ACKNOWLEDGMENTS

The authors would like to thank *Artur Popławski* for help in collecting data.

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