DERECHO - CHARACTERISTICS OF THE PHENOMENON, THE DANGER ZONE IN POLAND

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ABSTRACT. - Derecho - characteristics of the phenomenon, the danger zone in Poland. The aim of the paper is to characterize the occurrence of derecho phenomenon in Poland between 2007 and 2014 and to describe threats that this phenomenon causes. The number of derecho cases in Central Europe in that period was determined on the basis of the identification criteria proposed by R. Johns and W. Hirt. Also, conditions for the occurrence of derecho were characterized and destruction that it caused was described. Additionally, the ranges of the individual derecho cases enabled the determination of the most vulnerable areas of Poland to the occurrence of this phenomenon. Reports on dangerous meteorological phenomena, SYNOP and METAR reports, MSL pressure maps, upper air maps at 500 hPa and 850 hPa, upper air sounding plots, radar depictions and satellite images were used in this paper.

Keywords: derecho, mesoscale convective systems**,** Poland, occurrence areas, conditions of occurrence

1. INTRODUCTION

The area of Central Europe is exposed to the occurrence of different natural hazards. An examples of meteorological phenomena causing significant material damages and threatening people's lives are undoubtedly severe anemological events. In addition to the high wind speeds associated with deep low-pressure systems and large pressure gradient, foehn winds and tornadoes as well as the phenomenon of derecho belongs to the group of severe anemological events. This phenomenon is defined as a family of downburst clusters produced by mesoscale convective systems (Johns and Hirt, 1987). Severe anemological event can be named as a derecho after meeting defined criteria connected with its extent, development chronology, and temporal continuity.

There is a few available criteria to identify a derecho. The first researchers, who have developed a list of the specific conditions that must be met to consider phenomenon as a derecho were Johns and Hirt (1987). Later Bentley and Mote (1998), Evans and Doswell III (2001) and Coniglio and Stensrud (2004) have modified these criteria for their own research.

Most of research on the emergence and development of derechos is concentrated in the USA (Johns andHirt, 1987; Bentley and Mote, 1998; Evans and Doswell, 2001; Bentley and Sparks, 2003; Ashley et al., 2005;Coniglioet al.,2011).

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This is undoubtedly a consequence of the number of cases recorded in the USA per year (USA 15 cases per year, Europe several per year) (Coniglio and Stensrud, 2004). European studies primarily focus on the identifying the causes of occurrence of specific derecho cases (Gatzen, 2004; Punkka et al., 2006; Lopez, 2007; Pucik et al., 2011, Simon et al., 2011; Hamid 2012).The analysis of the multiannual derecho occurrence in Europe were conducted by Gatzen et al. (2011) and Celiński-Mysław and Matuszko (2014).Both American and European studies focus primarily on the analysis of synoptic situations conducting to the formation of mesoscale convective systems (MCS) known as the direct cause of derecho. These studies also focus on determining the corridors of movement of these phenomena and the identification of high-risk areas of derecho in Poland (i.e., Bentley and Sparks, 2003; Coniglio et al., 2004; Celiński-Mysław and Matuszko, 2014). These publications often also estimate risks linked to strong winds and present statistics of the number of victims and material damage (Ashley and Mote, 2005; Punkka et al. 2006; Fink et al. 2009).

The aim of the paper is to characterize the occurrence of derecho phenomenon in Poland between 2007 and 2014 and to describe threats that this phenomenon causes. Additional goal is to distinguish areas of Poland where occurrence of this phenomenon is the most frequent.

2. DATA AND METHODS

This study employed 6 identification criteria for derecho proposed by Johns and Hirt (1987):

1. There must be a concentrated area of convectively induced wind gusts greater than 26m/s that have a major axis length of 400 km or more;
2. The wind reports must have chronological progression;
3. No more than 3 h can elapse between successive wind reports;
4. There must be at least three reports of either F1 damage or wind gusts greater than 33 m/s separated by at least 64 km during the MCS stage of the event;
5. The associated MCS must have spatial and temporal continuity;
6. Multiple swaths of damage must be part of the same MCS as indicated by the available radar data.

Data from 2007-2014 helped in verifying identification criteria for derecho. The input data included: reports on dangerous meteorological phenomena from the on-line service European Severe Weather Database (http://essl.org/cgi-bin/eswd/eswd.cgi) and news bulletins about the effects of severe storms from the on-line service Polish Storm Chasers - SkywarnPolska (http://lowcyburz.pl/), SYNOP and METAR reports (http://www.ogimet.com), MSL pressure maps (http://www.knmi.nl, http://pogodynka.pl, http://www.wetter3.de), upper air maps at 500 hPa and 850 hPa(http://www.estofex.org), radar depictions (Institute of Meteorology and Water Management — National Research Institute, http://www.lightningmaps.org, http://www.meteox.com), satellite images (http://www.sat24.com) and upper air sounding plots (http://www.weather.uwyo.edu).

The research process was divided into3 stages. The first stage involved reviewing reports on severe weather events (European Severe Weather Database) and news bulletins about the effects of severe storms (on-line service Polish Storm Chasers – Skywarn Polska). The review helped in selecting these severe anemological events, which were recorded over large areas of Central Europe and met the first 3 derecho criteria proposed by Johns and Hirt (1987). Second stage of the study focused on 37 selected cases. For these cases, reports on wind speeds exceeding 26 m/s were complemented based on SYNOP and METAR reports. It allowed eliminating cases with no matching reports of such winds (≥ 26m/s) within or very close to the Polish national border. Cases characterized with maximum wind speeds coincided in time with a maximum pressure gradient rather than with the passage of a front (convective system) (it was verified basing on archive synoptic maps and reports dates) were eliminated. Additionally, cases which have not met criterion 4, were eliminated (these cases, where at least three reports were of either F1 damage or wind gusts greater than 33 m/s, but the distance between two reports was less than64 km for the analysis satellite and radar data were allowed). The third stage included an analysis of satellite and radar data, which helped in verifying the final two identification criteria.

Methodology used in this study allowed to conclude that between 2007-2014, 10 severe anemological events, which could be classified as a derecho, occurred in Poland (Table 1).

Table 1. ***The list of severe anemological events in Poland during the period 2007-2014, which were classified as a derecho***

No.	Onset (UTC)	End (UTC)	After verification of identification criteria
2007			
1.	18 January at 13:00	19 January at 03:00	***Derecho***
2008			
2.	26 January at 12:00	27 January at 00:00	***Derecho***
3.	1 March at 03:00	1 March at 18:00	***Derecho***
4.	25 June at 12:00	25 June at 22:00	***Derecho***
2009			
5.	23 July at 15.00	23 July at 22:00	***Derecho***
2010			
6.	11 June at 06:00	11 June at 18:00	***Derecho*** (3 reports on winds exceeding 33 m/s or F1 damage, the distance between two reports below 64 km. Decision was made to declare the case as a derecho)
2011			
7.	22 June at 13:00	22 June at 22:00	***Derecho*** (3 reports on winds exceeding 33 m/s or F1 damage, one at Szonowice (Silesia) and the remaining cases clustered together within ca. 20 km. Decision was made to declare the case as a derecho).
8.	20 July at 08.00	21 July at 00.00	***Derecho***
2012			
9.	6 August at 17:00	7 August at 01:00	***Derecho***(A report on wind speed of 32.5 m/s in Rybnik accepted to fulfill criterion 4)
2013			
10.	29 July at 14.00	30 July at 04.00	***Derecho***

Source: prepared by the author

Synoptic, kinematic and thermodynamic data (obtained from MSL pressure maps, upper air maps at 500 hPa and 850 hPa, upper air sounding plots)for the selected cases of derecho were used for identification of factors particularly conductive to the development of this phenomenon. The ranges of the individual derecho cases enabled the determination of the most vulnerable areas of Poland to the occurrence of this phenomenon.

3. AREAS OF OCCURRENCE OF DERECHO PHENOMENON IN POLAND

Methodology used in this study allowed identifying 10 derecho cases, which occurred in Poland in the research period. Three of them occurred in the cool season (2 cases in January, 1 case in March), the remaining 7 in the warm season (3 cases in June, 3 cases in July, 1 case in August) (tab. 2). The ranges of the individual derecho cases enabled the determination of the most vulnerable areas of Poland to the occurrence of this phenomenon. Undoubtedly Lower Silesia and South Great Poland need attention. In this area 5-6 of 10 recorded cases of derecho occurred. The analysis showed also that the edges of the Eastern Poland, Kujawy area and the coast of the Baltic Sea were entirely free from this phenomenon in the research period (Fig. 1).

The movement tracks of the mesoscale convective systems showed the existence of certain regularities. Cool-season derecho cases were always associated with convective systems, which developed on the cold front of a deep low-pressure system (deep depression) (3 cases). These systems always moved from the northwest. Warm-season derecho cases, in turn, were associated with systems, which emerged from the warm sectors of depressions in areas of wind convergence in the lower troposphere (4 cases) or from secondary, but very active depression, which formed on an articulated cold front (or from cold front of this secondary depression) (3 cases). In the warm season convective systems travelled from west, southwest or south to east, northeast or north (Table 2, Fig. 2).

The differences between cool-season and warm-season derecho cases can be observed also during the analysis of the moving distance of the mesoscale convective system and during the analysis of the width of the zone within which strong wind gusts and significant material damages were recorded. In the cool season, the maximum width of derecho zone reached 600-700 km, and the mesoscale convective systems causing derecho travelled to 1000-1500 km. Warm-season derecho cases are characterized by narrower zones of damages (from ~40 to ~290 km), and convective systems travelled over shorter distances (from ~500 to ~860 km).

Cool-season derecho is usually characterized by more number of reports on wind speeds exceeding 26m/s or the damage it caused.

These reports covered also larger area of Poland than reports related to warm-season derecho. In the cool season, within derecho zone also more places with wind gusts exceeding 33 m/s or more were reported, and damage caused by mesoscale convective systems reached even F3 on the Fujita scale (case of 1st March 2008 – report from Austria).

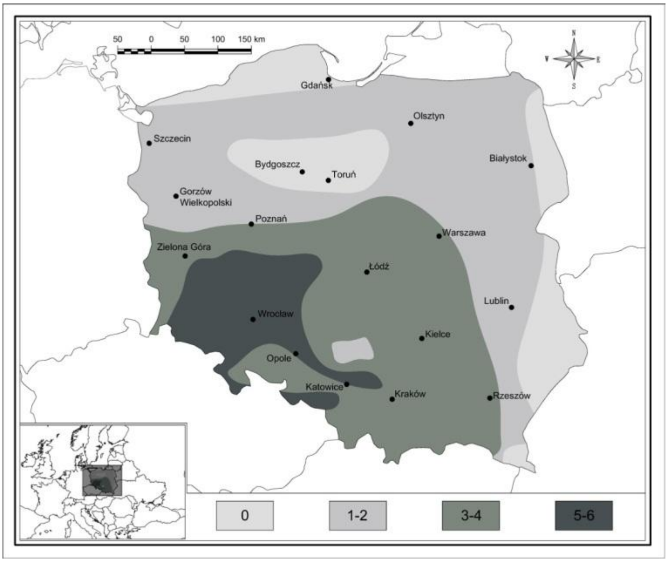

Fig. 1. ***The occurrence of derecho phenomenon in Poland - total number of derecho cases occurring between 2007 and 2014 in Poland (prepared by the author)***

4. THE CONDITIONS FAVOURABLE TO THE DEVELOPMENT IN POLAND

The analysis of the synoptic, kinematic and thermodynamic data for individual cases, helped in identifying of the conditions conducive to the formation of derecho phenomenon in Central Europe.

Table 2. ***The causes of formation of mesoscale convective system and the types of derecho phenomenon in Poland.***

Date	The causes of formation of mesoscale convective system	Type		
		Structure	Conditions of development	Time of occurrence
18 January 2007	Cold front	Serial derecho	Strong forcing derecho	Cool-season derecho
26 January 2008	Cold front	Serial derecho	Strong forcing derecho	Cool-season derecho
1 March 2008	Cold front	Serial derecho	Strong forcing derecho	Cool-season derecho
25 June 2008	Areas of wind convergence	Progressive derecho	Weak forcing derecho	Warm-season derecho
23 July 2009	Areas of wind convergence	Hybrid derecho	Weak forcing derecho	Warm-season derecho
11 June 2010	Secondary very active depression (cold front of this depression)	Hybrid derecho	Hybrid derecho	Warm-season derecho
22 June 2011	Areas of wind convergence (close to cold front)	Serial derecho	Hybrid derecho	Warm-season derecho
20 July 2011	Areas of wind convergence	Progressive derecho	Weak forcing derecho	Warm-season derecho
6 August 2012	Secondary very active depression	Progressive derecho	Weak forcing derecho	Warm-season derecho
29 July 2013	Secondary very active depression	Hybrid derecho	Weak forcing derecho	Warm-season derecho

Source: prepared by the author

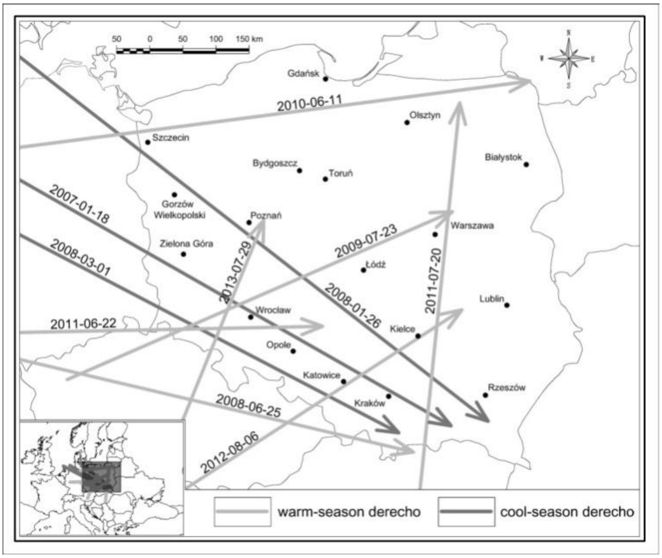

Fig. 2. ***The movement tracks of the mesoscale convective systems over Poland, which caused derecho (prepared by the author)***

Upper air maps at 500 hPa showed that the occurrence of derecho cases was accompanied by a trough moving over Poland. A divergence zone of a trough deepened the existing depression and intensified convective processes on the cold front or in a warm area of this depression. It also influenced the development of an extensive squall line.

Advection of very cold air masses from higher latitudes within the trough caused increase of the horizontal temperature gradient. Within the transition zone, at the boundary of air masses of different temperature, the jet stream developed. The presence of the jet stream boosted the energy of the tropospheric processes. The jet stream has played particularly important role in the formation of the cool-season derecho. In the cool season, at the height of 500 hPa, within the jet, the wind speed reached even to 70 m/s (case of 18th January 2007). Very strong air flow in the mid and high troposphere significantly increased values of vertical wind shears, which provided a good separation between updrafts and downdrafts. Very powerful air flow in troposphere also allowed the development of a strong gust front in cool season despite very low thermodynamic instability. The analysis of upper air sounding plots, which were made in a short time before gust front arrival, showed that the wind shears across the bottom 3 km of the troposphere in the cool season reached even 40.2 m/s (case of 1st March 2008 – upper air sounding in Lindenberg at 06.00 UTC). The wind shears across the bottom 6 km of the troposphere, in turn, reached even 44.1 m/s (the same case).

Upper air sounding plots at 850 hPa, helped in identifying of advection direction of air masses ahead of the front zone (ahead of mesoscale convective system). In each derecho case in Poland, a hot (warm in cool season) and humid air mass ahead of the front zone was coming from the south and southeast. The advection has played particularly important role in the warm season. The high instability of air masses (as confirmed by upper air soundings), which flowed ahead of travelling convective systems, increased the energy of these systems and extended their life thus allowing them to travel over long distances. The thermodynamic parameters of warm-season derecho cases reached very high values (Table 3).

Table 3. ***The thermodynamic parameters received from upper air soundings (case of 23rd of July 2009, 12:00 UTC)***

Location and time of soundings	**The thermodynamic parameters received from upper air soundings**					
	SBCAPE [J/kg]	DCAPE [J/kg]	LI [□C]	K Index [□C]	Delta theta-e [□C]	Cold pool strenght [□C]
Legionowo	1590	790	-4.9	30.9	16.9	13.5
Prague	3690	1100	-9.5	28.1	27.2	13.5
Wroclaw	2500	1020	-7.4	30.5	21.5	14.1

Source: prepared by the author

5. CONCLUSIONS

The extended by a further years analysis and a slightly liberalization of the identification criteria for a derecho (comparing to research Celiński-Mysław and Matuszko 2014), allowed to identify in the research period ten anemological events in Poland, which could be classified as a derecho. The analysis occurrence areas of derecho phenomenon in Poland leads to the following conclusions:

- the most vulnerable to the occurrence of derecho phenomenon in Poland area is the Lower Silesia and South Great Poland;
- the edges of the Eastern Poland, Kujawy area and the coast of the Baltic Sea were entirely free from this phenomenon in the research period;
- in the cool season, comparing to warm season, mesoscale convective systems causing derecho travelled over a longer distance, and derecho zone was wider and covered a larger area of Poland.

The analysis of synoptic, kinematic and thermodynamic data for all derecho cases, in turn, helped in identifying of the conditions conducive to the formation of derecho phenomenon in Central Europe:

- in the cool season: a cold front of a deep depression;
- in the warm season: an area of wind convergence in a warm sector of a depression or secondary, but very active depression;
- the presence of a divergence zone of a trough moving over Central Europe;
- the occurrence of a strong jet streams in the upper and middle troposphere (especially in the cool season);
- the high instability in the troposphere (especially in the warm season).

The research also allowed drawing following conclusions:

- mesoscale convective systems causing derecho formed over Poland, more than two times often in the warm season than in the cool season;
- the access to military database and to Trax system database (network of road meteorological stations) may lead to conclusion, that some severe anemological events were wrongly eliminated (for example because of lack of reports on wind speeds exceeding 33 m.s-1). Possessing this data could make the number of derecho cases higher;

- probably the number of derecho cases will be higher, when identification criteria proposed by Bentley and Mote (1998) or Evans and Doswell III (2001) will be used.

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