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# An analysis of selected cases of derecho in Poland

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ABSTRACT

The paper analyses six cases of the derecho phenomena, which occurred in Poland between 2007 and 2012. The input data included reports on dangerous meteorological phenomena, SYNOP and METAR reports, MSL pressure maps, upper air maps at 500 hPa and 850 hPa, radar depictions and satellite images, upper air sounding plots and data from a system locating atmospheric discharges. Derechos are caused directly by the activity of mesoscale convective systems linked up with either, in winter, a cold front of a deep low-pressure system, or, in summer, with an area of wind convergence in a warm sector of a cyclone or with an articulated cold front which, moving within a low-pressure embayment, develops a very active secondary depression. It was found that southern and central Poland were the regions most frequently affected by derechos. Mid-level and high-level jet streams, augmented by high thermodynamic instability of air masses, were found to be conducive to the development of derechos.



## 1. Introduction

The derecho is one of the most dangerous anemological phenomena and one that is very little understood. Yet its destructive nature and long reach have produced an increasing interest among researchers. Much existing research on the emergence and development of derechos is concentrated in the USA (Johns and Hirt, 1987; Evans and Doswell, 2001; Bentley and Sparks, 2003), which is clearly linked to the number of occurrences recorded there (on average 15 cases per year compared to individual cases in Europe) (Coniglio and Stensrud, 2004). Both American and European studies focus primarily on the analysis of synoptic situations conducive to the formation of mesoscale convective systems (MCS) known to be the direct cause of derechos (Johns and Hirt, 1987; Coniglio et al., 2004, 2011, 2012; Gatzen et al., 2011; Pucik et al., 2011; Hamid, 2012). Another aspect taken up by the available research includes the identification of routes travelled by derechos and the zoning of areas of increased risk (Bentley and Mote, 1998). Some authors (Ashley and Mote, 2005; Punkka et al., 2006; Fink et al., 2009) also estimate risks linked to strong winds, such as potential casualties and material damage.

The objective of this study is to characterise selected occurrences of the derecho phenomenon in Poland, including an analysis of the accompanying synoptic situation, and to identify conditions favourable to the development of derechos in Central Europe.

There is a range of definitions and criteria available to identify a derecho (Johns and Hirt, 1987; Bentley and Mote, 1998; Coniglio and Stensrud, 2004). A derecho is defined as a large-scale and persistent zone of strong straight-line wind caused typically by a mesoscale convective system (MCS), where high wind speeds are caused by strong downdrafts reaching the surface of the earth. This study employed the six identification criteria for a derecho proposed by R.H. Johns and W.D. Hirt (1987):

1. There must be a concentrated area of convectively induced wind gusts greater than 26 m $s^{-1}$ that has 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;

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4. There must be at least three reports of either F1 damage or wind gusts greater than 33 m $s^{-1}$ 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.

The study uses data from the period 2003–2012, including reports on dangerous meteorological phenomena from the on-line service *European Severe Weather Database* (http://essl.org/cgi-bin/eswd/eswd.cgi), reports from SYNOP (*Surface Synoptic Observations*) and METAR (*Meteorological Aerodrome Report*), MSL pressure maps (http://www.knmi.nl, http://www.wetter3.de), upper air maps at 500 hPa and 850 hPa (http://www.estofex.org), radar depictions, satellite images, upper air sounding plots and data from the Perun atmospheric discharge location system made available by the Polish Weather Service (Institute of Meteorology and Water Management — National Research Institute).

The first step involved reviewing reports on severe weather events recorded over large areas of Central Europe between 2003 and 2012 and available in the on-line *European Severe Weather Database*. Suitable anemological events which met the first three derecho criteria proposed by R.H. Johns and W.D. Hirt (1987) were then selected.

In the second step, the study focused exclusively on the 28 events selected and these reports were paired with data on wind speeds higher than 26 m $s^{-1}$ obtained from SYNOP and METAR reports. Events that had no matching reports of such winds within or very close to the Polish national border were eliminated. The same treatment was applied to those events whose maximum wind speeds coincided in time with a maximum pressure gradient rather than with the passage of a front (convective system), as well as to those that failed on criterion 4. In this way the group of potential derecho candidates was narrowed down to 11 (Table 1).

An analysis of satellite and radar data helped verify the final two identification criteria. Due to the unavailability of radar data from the Polish POLRAD system for the period before 2008 and due to the limited availability of radar data from online services http://www.meteox.com/hist.aspx?URL and http://europa.buienradar.nl/hist.aspxa decision was taken to limit the period analysed to 2007–2012.

The method proposed by R.H. Johns and W.D. Hirt (1987) was used to verify the samples in this step and yielded six derecho events during the period 2007–2012 (Table 2).

## 2. Analysis of derechos in Poland

### *2.1. 18 January 2007*

The first of the derechos was linked to the passage of a deep depression ("Kyrill") over the North Atlantic and Europe. A long squall-line several hundred kilometres long developed on its cold front. This travelled over Poland on 18 and 19 January 2007 causing damage over a large area of the country. The wind speeds peaked during the passage of the cold front and immediately after it, i.e. when the atmospheric circulation changed from S–SW to W–NW, rather than when the pressure gradient over Poland was at its highest (surface pressure difference of 35 hPa over 650–700 km). In Germany, between their northern and southern borders, there was a surface pressure difference of 45 hPa, corresponding to a pressure gradient of 5.5 hPa/100 km (Gatzen et al., 2011). The cold front crossed Polish territory in a mere few hours (Fig. 1). The highest wind speeds were recorded between 18:00 UTC on 18 January and 0:00 UTC on 19 January 2007 (Fig. 2) and there were also cases of force F2 tornados. The passage of the cold front was also accompanied by intensive rainfall. A very strong jet stream was detected on upper air maps at a height of 500 hPa with speeds of up to 70 m $s^{-1}$ (and of up to 45 m $s^{-1}$ at 850 hPa). The presence of a strong jet stream contributed to the development of high vertical wind shears, which provided a good separation between updrafts and downdrafts. The strongest contributor to the development of the gust front was the alignment of the MCS alongside the cold front. Since the timing of the Lindenberg sounding (near Berlin) was just about 30 min before the arrival of the gust front, it should also be regarded as the most faithful representation of the conditions existing before the front zone in Poland (especially when compared to the Prague sounding at 3 h and Wrocław sounding about 8 h before the gust front). A trough divergence zone also contributed to the deepening of the depression and to the intensification of processes active along the squall line. At 12:00 UTC, the trough axis was over the eastern part of Great Britain and travelled eastwards towards Poland. Upper air maps at 850 hPa depicted a mass of warm air pushing into Poland from the west and southwest ahead of the cold front. The cold front moving in from the northwest rapidly pushed out the warmer and more humid air with much cooler air from the north and northwest. (At this height the temperature in south-western Poland ahead of the front was up to 6 °C only to drop below 0 °C after its passage). The kinematic and thermodynamic conditions ahead of the cold front and its squall line were determined using upper air sounding plot records from (Fig. 3) Lindenberg (at 18:00 UTC), Prague (at 18:00 UTC) and Wrocław (at 12:00 UTC). Their analysis suggests that the air temperature at ground level was very high for this season at more than 10 °C (including 14.4 °C at 2 m above ground in Lindenberg, but that it had dropped to 6 °C after the passage of the front). In the mid and high troposphere a very powerful air flow caused the occurrence of a steep vertical temperature gradient and very high wind shear recorded at Lindenberg (0–3 km shear = 32.8 m $s^{-1}$, 0–6 km shear = 24.0 m $s^{-1}$), in Prague (0–3 km shear = 40.1 m $s^{-1}$, 0–6 km shear = 41.5 m $s^{-1}$) and in Wrocław (0–3 km shear = 26.4 m $s^{-1}$, 0–6 km shear = 36.2 m $s^{-1}$). The most unstable convective available potential energy (MUCAPE) of the air masses before the front zone was 20 J · $kg^{-1}$ (MUCAPELindeberg). While this value was relatively low, it could have combined with the effects of the rapid airflow and with strong and large-scale upward flows linked with, among other factors, the dynamic high wave (trough) travelling through Poland, and thus contributed to the development and energising of a broad squall line with tornados. The K index values recorded, up to 31 °C, suggested the possibility that there was a very strong convective system with thunderstorm activity accompanying the very high wind shear. The K index is calculated on the basis of the air temperature gradient in the lower troposphere and on the basis of humidity.

The derecho of 18 January 2007 met all the identification criteria (Fig. 2). The MCS caused damage along a strip 1000 km