Briefly about the derecho event over Poland in 11 August 2017

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1 Introduction

The derecho of 11 August 2017, commonly known as Suszek, was the most catastrophic weather event in Poland of the last decade. This case of a violently and very fast moving MCS is very different from the cases of tornadoes generated by the classical, large and slowly moving supercells (Parfiniewicz and Baranski, 2014). Here, the jet stream, located, above the western border of Poland, decided about supporting convection and moving it to the northeast (Taszarek et al., 1919). To divide the day of the considered violent derecho incident into the particular stages of its evolution, we used 144 scans of the Virtual Fujita Scale [VFS] obtained from the PERUN (here PERUN is the own name of Polish lightning location and detection network operated by the IMWM-NRI) lightning data and according to the formulas described previously in the COSMO Newsletters No. 13, 14, 16. It resulted that this particular day with derecho incident was divided into 3 different stages of its development, i.e., the 1-st stage occurring before 04:40 UTC and obeying the very strong storm convection preceding the derecho episode, the 2-nd lasted from 04:50 to 12:30 UTC as the intermediate stage and finally the 3-rd one lasted from 12:40 to 23:50 UTC as such catastrophic episode of violent convection which swept over Poland. Let us note, after (Mańczak et al., 2021), that the detailed synoptic analysis confirmed that the 1-ststage was especially "important for the development of the synoptic situation". It was also confirmed by reports from the European Severe Database (see also Lelatko I., 2020) that were given in the time interval from 10.08.2017 09:00: UTC to 11.08.2017 03:00 UTC. In turn, the time moment 12:40 UTC was accepted as the beginning of the 3-rd stage. Then the linear storm zone from the South Bohemia changed the direction of movement from the SEE-NNW to SSW-NNE. In practice, this direction remained unchanged until the end of the derecho episode, i.e. until 23:50 UTC.
Key words: Derecho, convection, convection system, propagation path, movable filter, lightning location system. **Brief characteristics of the 3 stages**

2 Propagation of the convection system in the 3rd stage.

The reconstruction of the disturbance propagation can be estimated from the wind trajectories, the path of destruction, and direct tracing of the movement of storm cells. In our study of this episode we have used the procedure of sliding movable filters on sixty-eight 10-minute scans from the PERUN lightning location and detection system storm telemetry, that turned out to be effective and relevant. The essence of the approach is the coherence of the images of electrical activity manifested in the neighboring scans (we assume that the 10-minute resolution allows the recognition of basic identities).
The first attempt was to identify propagation leaders. It turned out that while storm cells (clustered together) allow them to be unequivocally identified, the designation of "propagation leaders" is not distinctly expressed because the cells exchange "leadership". This is how the first version of the main and side track was created. Then, using the moving filter method, the weighted average on the filter and the variant division into left and

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right paths were determined. The detailed analysis of individual scans shows that around 19:30 the process of propagation splitting into 2 paths begins. At 21:30 the convection system is definitely divided into two branches - one blow (the right track end) went to Kurland and the other to the Bay of Gdańsk. The final dissipation of this stage, as based on the EA evaluation, begins and lasts until 23:50.

The above estimated propagation paths were used to determine the speed of disturbance displacement. The total distance - 864.42 km, traveled in 11.17 hours. with an average speed of 21.50 m/s (77.4 km / h). The highest speeds (up to 40 m/s) were estimated during the propagation splitting stage (from 19:30 to 21:30 UTC) and separating the track into two branches left and right. The right branch remains the main branch and the speeds have been estimated on it. The estimated speed is derived from the position which was determined by the moving filter. We have illustrated such assessment by the example given below for two neighboring scans, i.e., for the time 21:20 and 21:30.

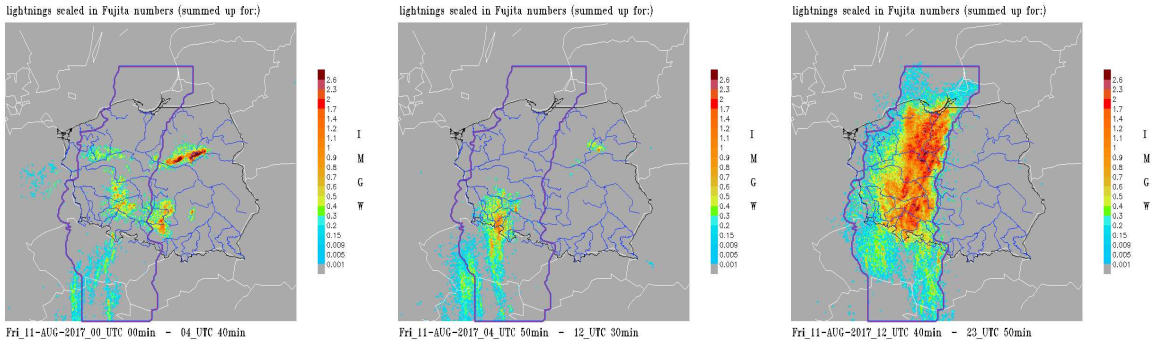

Figure 1: Fig.1. Electric Activity (EA) summary maps (signatures) of the „F (x, y, t) =¿ Fmax (x, y)" /time type in Fujita numbers (VFS). The 3rd stage explains and defines the event "mask" as the boundary of the area of all detected lightning discharges in this stage.

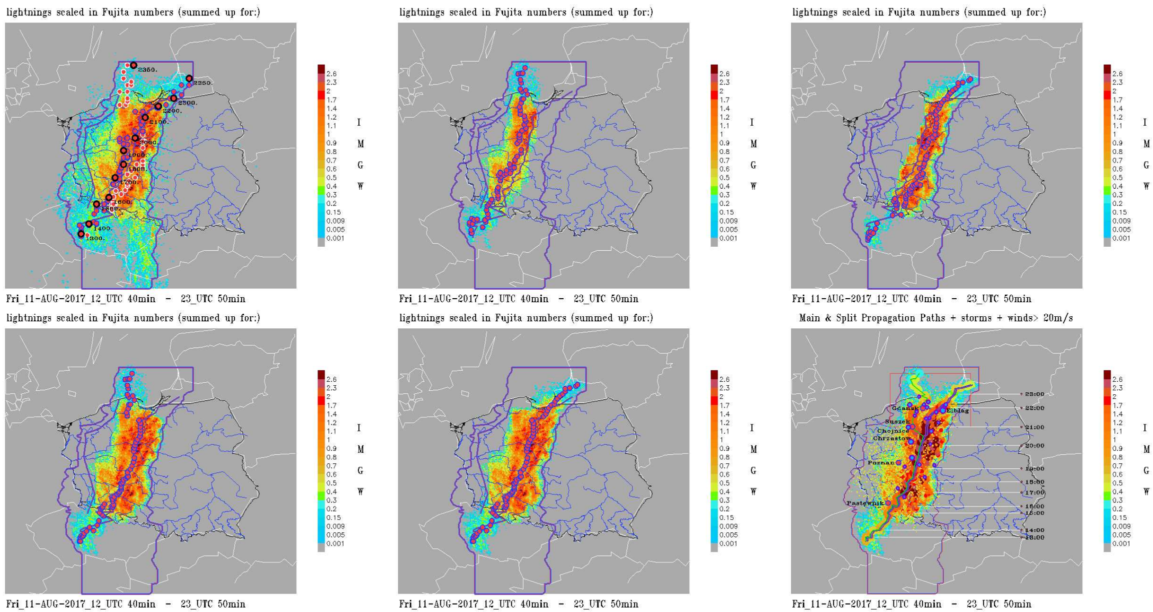

Figure 2: [2.1-2.6]. Estimation of the disturbance propagation path. Subsequent estimates: Fig.2 / [2.1] main and side track, Fig.2 / [2.2-2.3] separated left and right tracks, Fig.2 / [2.4-2.5 left and right tracks on the entire filter, Fig. 2 / [2.6] final (merged) result including the process of propagation splitting.

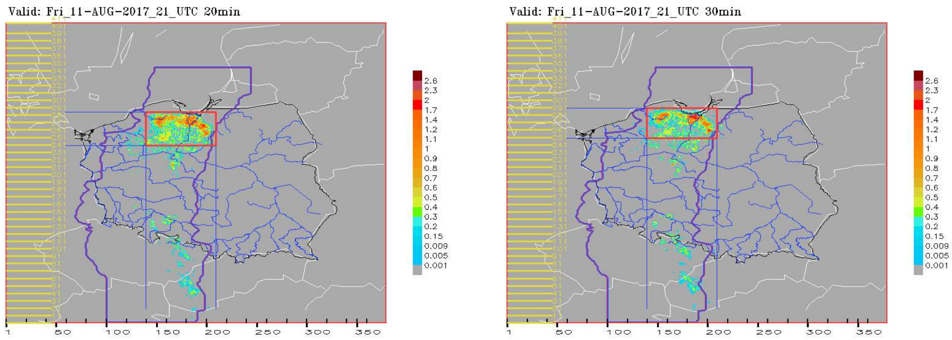

Figure 3: [3.1-3.2] "Movable filter" - a tool that allows to define the current position of the active disturbance area in relation to the calculation grid used (here COSMO 2.8km). The example concerns 2 neighboring scans 21: 20,21: 30.

On the basis of the main path, it was possible to estimate the propagation velocities.

3 Supplements

3.1 Example of reflectivity scans for Gdańsk and Poznań

To understand the considered strong convection process it requires a separate detailed non-hydrostatic diagnosis (¡0.3 km) with assimilation procedure that includes Doppler winds on each of the 68 scans. Conducting of such task takes a lot of time and work. So far, quasi 3D reflectivity scans for Poznań and Gdańsk have been made. Below we present them for two selected time moment: for 17:00 UTC given by the reflectivity in dBZ together with the Doppler wind for the alleged formation of supercell and for 21:30 UTC, , i.e., obtained after 50 min. from the estimated moment of split.

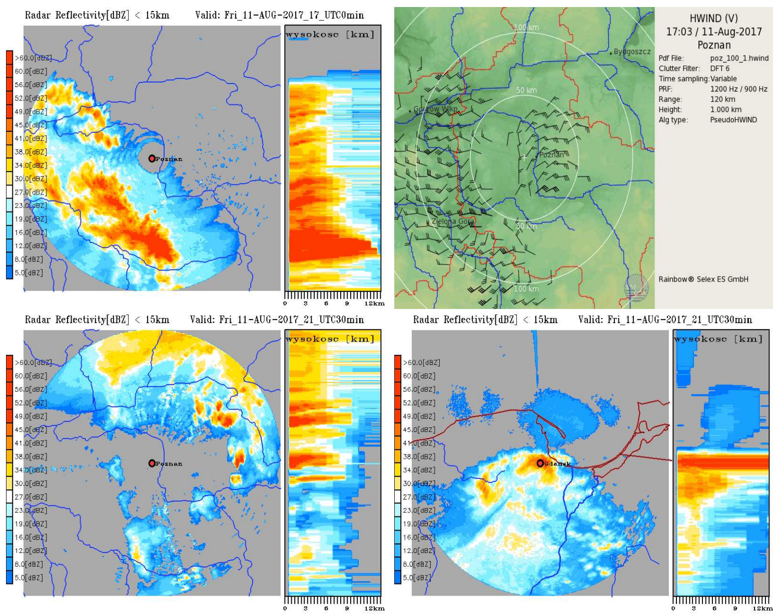

Figure 4: [4.1-4.4]. Doppler & Quasi 3D scans (maxcappi Z - XY, and X - ZY) of reflectivity for Poznań and Gdańsk. The scans were preceded by interpolation of the measured reflectivity (Z: 1km -18km, XY: 0.7 km) to the computational grid with dz = 250m.

At this time the signature of bow echo and rear inflow jet are rather weak to see. But what is characteristic in this case, is the vertical cylinder of maximum reflectivity that is reaching the stratosphere. Here, it should be noted for clarification, that after 20 minutes later, both bow echo and rear inflow jet are emphatically expressed.

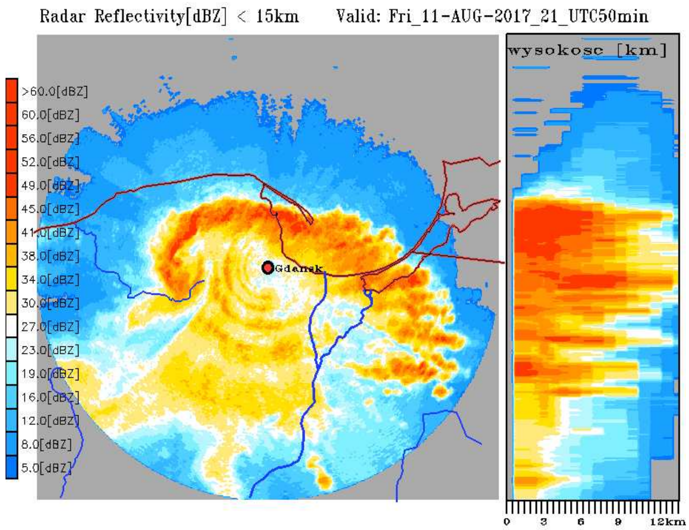

Figure 5: Quasi 3D reflectivity scan for Gdańsk radar at 21:50 UTC showing a clear bow echo and rear inflow jet/RIJ structure.

3.2 Looking for the coherent impact structures connected to the considered derecho incident.

Two results obtained from the simulation with the COSMO 2.8 km model with a time resolution of 15 minutes are worth presenting.

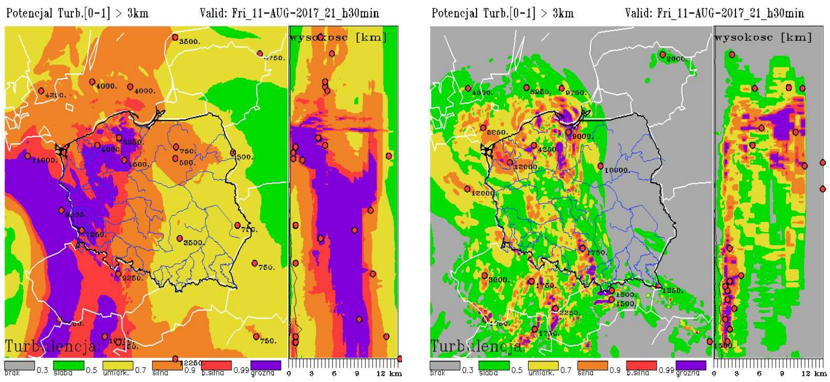

Figure 6: [6.1-6.2]. Slightly modified results of operational forecasts of turbulence over Poland broken down into 2 components of Reynolds and Richardson in the "maxcappi" Z-XY and X-ZY system; Z axis: 0-15 km.

These calculations are derived from an operational turbulence forecasting tool. Here they have been divided into 2 components, i.e. Reynolds and Richardson numbers, respectively. The Reynolds number, let's recall it here α^* ϱ^* V is just momentum. Another association is root square of kinetic energy. The Richardson number, as is well known, is measure of atmosphere stability. Generalizing the Bernoulli principle, these quantities - especially energy and momentum - should be invariants of the trajectory. Thus, the momentum in particular, indicates well that the sources of ground wind force are related to the middle and upper troposphere. Here, it should be noted that also the GFS analysis for the level of 300 mb has located jet stream over the western border of Poland.

3.3 Wind through trajectories

For several years, the operational weather service has been calculating the 850 mb trajectories for selected four stations in Poland. The ones presented below well reflect the wind dynamics during the considered derecho day.

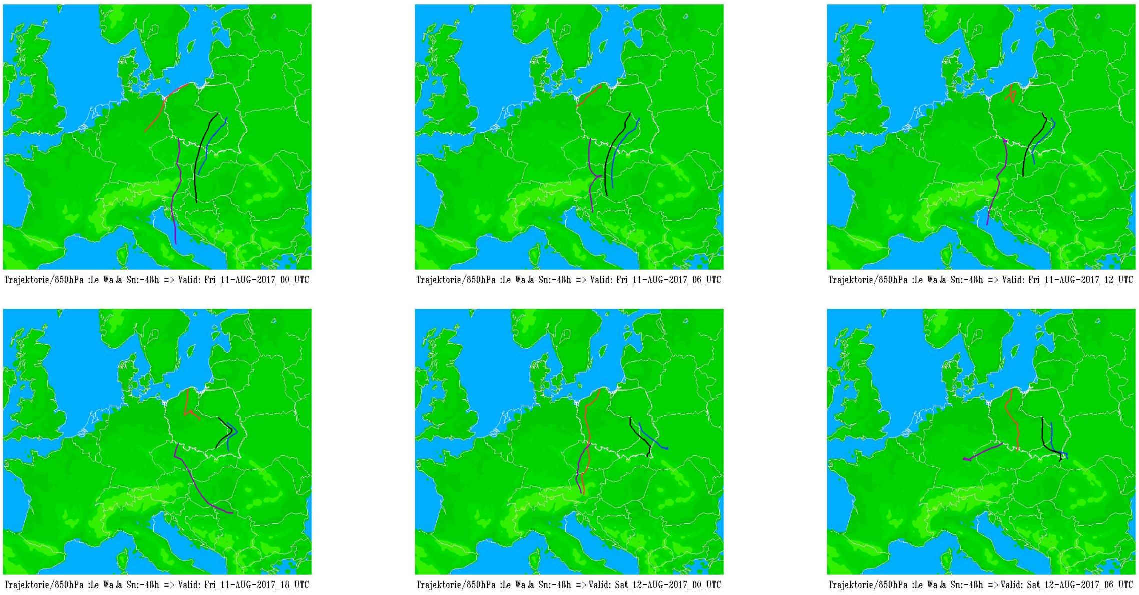

Figure 7: [7.1-7.6]. Trajectories for the level of 850 mb and the time interval of 48 hours and for 4 selected places in Poland, i. e., for Łeba, Jarczew, Śnieżka and Warsaw from the dates: 2017081100, 2017081106, 2017081112, 2017081118, 2017081200 and 2017081206.

4 Conclusions

In light of electrical activity it was not a strong convective event (max 3.6 VFS).This indicates that the decisive factor here was the forcing of the synoptic scale, possibly related to the middle and upper troposphere, and even the stratosphere (case 17:00 over Poznań, case 21:30 over Gdańsk). The highest estimated speeds (up to 40 m/s) occurred around 19:30 UTC, preceding the split stage. The estimated velocity of propagation compared with the telemetry data and damage measurements, especially in the stage from 19:30 to 21:30 UTC, have matched the VFS numbers quite well. Understanding the process requires a separate detailed non-hydrostatic diagnosis (¡ 0.3 km) with assimilation procedure that includes Doppler winds on each of the 68 scans, and then merging these 68 domains (3D fields of meteorological elements) into one whole. This is just an introduction and an incentive to achieve this goal . As for the forecast, the collected material allows any thunderstorm prediction method to be validated. The results of the operational calculations using the stability indices method (LPP: Lityńska, Parfiniewicz, Piwkowski 1976) and the "thunderstorm thermometer" approach (Parfiniewicz 2014) are promising (Barański and Parfiniewicz 2019).

References

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