12th European Conference On Severe Storms
Utrecht, The Netherlands
November 17 – 21 2025
P72 | ECSS2025-308

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Advancements in Automated Convective Cell Detection and Nowcasting at Deutscher Wetterdienst (DWD)

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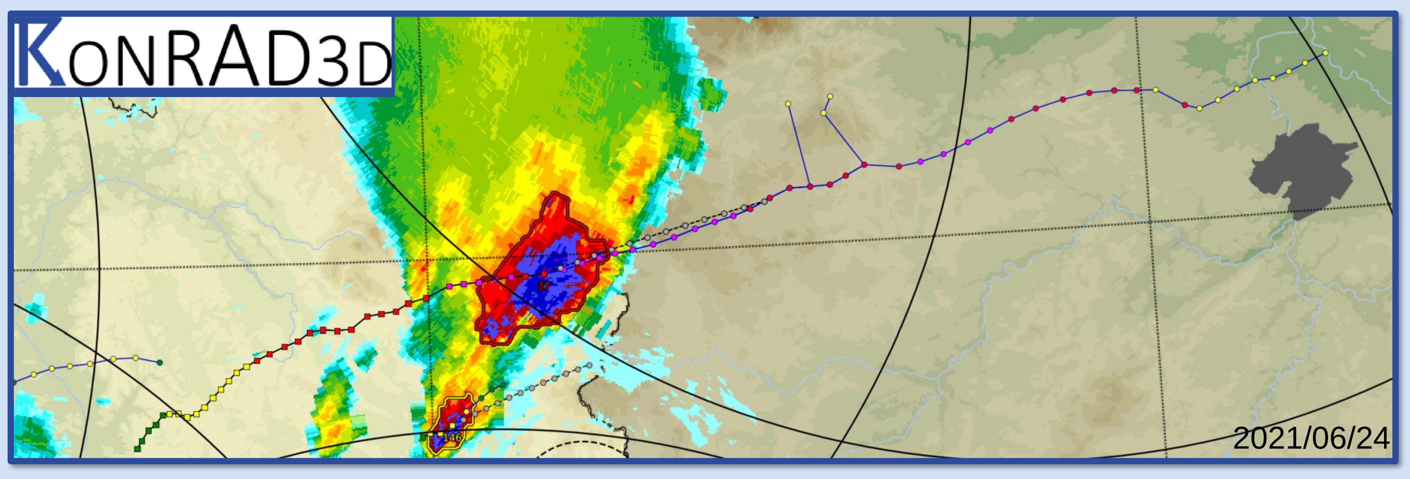
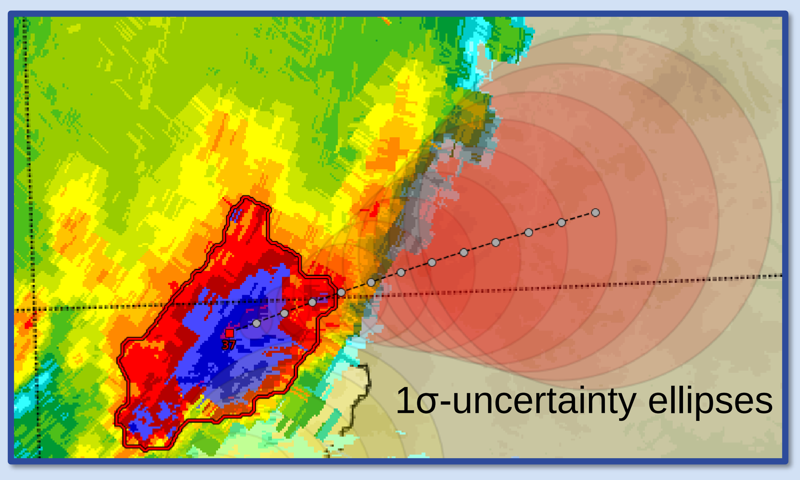
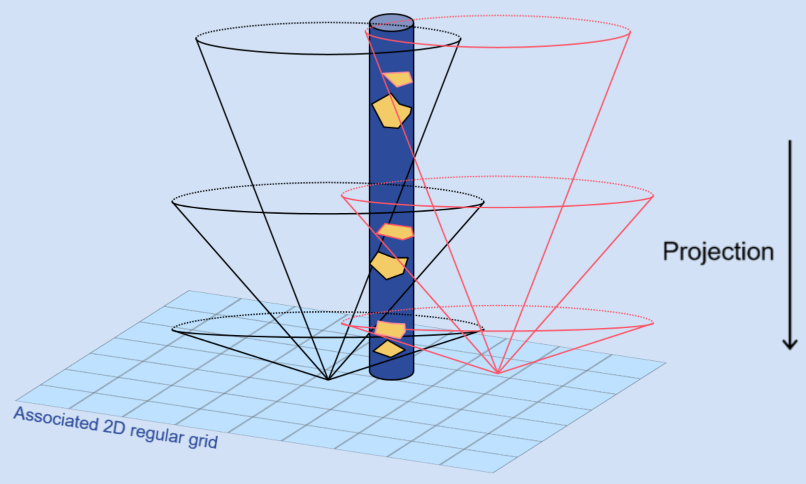
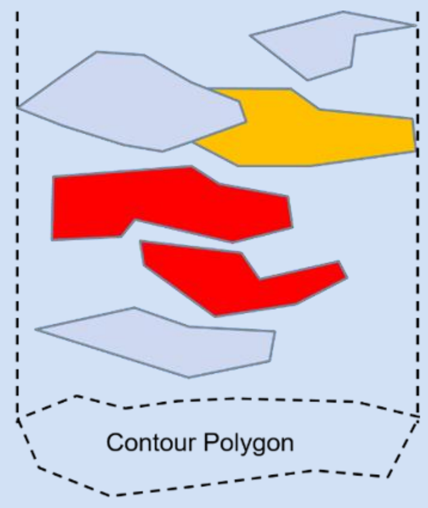








KONRAD3D is a tool for the automated detection, tracking, and nowcasting of convective cells developed at the Deutscher Wetterdienst (DWD). It has been in operational use since April 2023. Every five minutes, KONRAD3D generates an XML output file containing information on all currently detected convective cells, including links to predecessor objects. The data are publicly available through https://opendata.dwd.de/weather/radar/konrad3d/ . As the main data source for cell detection, 3D radar reflectivities from 17 operational DWD weather radars are used. In addition, 3D hydrometeor classification, lightning data (LINET), gridded rain gauge-adjusted QPE products, mesocyclone detections, satellite data and NWP fields are incorporated. In total, more than 200 attributes are derived in several categories: metadata, geometry, intensity, hymec, NWP model, lightning, mesocyclone, tracking, and forecast. A Kalman filter is applied to estimate cell location, velocity and acceleration, resulting in stable analyses and nowcasts. The filter also provides uncertainty ellipses around forecast centroids supporting probabilistic interpretation of cell motion.

Long-term KONRAD3D dataset

At DWD, the dataset **LUMINA** (*__L__ong-term __U__nified __M__eteorological data for __IN__put to __A__I-driven nowcasting and short-term forecasting)* has been created. KONRAD3D data from 01.03.2018 up to 30.06.2025 is part of it. We use this period to perform various verifications and statistical evaluations of KONRAD3D.

Verification of cell polygon and forecast centroids against lightning data

Lightning strokes inside a cell polygon are counted as hits, while those outside all polygons are counted as misses (see Figure 1). We also consider circles around analysis and forecast centroids with radii equivalent to the area of the cell polygon as well as inflated versions of these circles to assess forecast performance (Figure 2). Hits and misses are defined analogously.

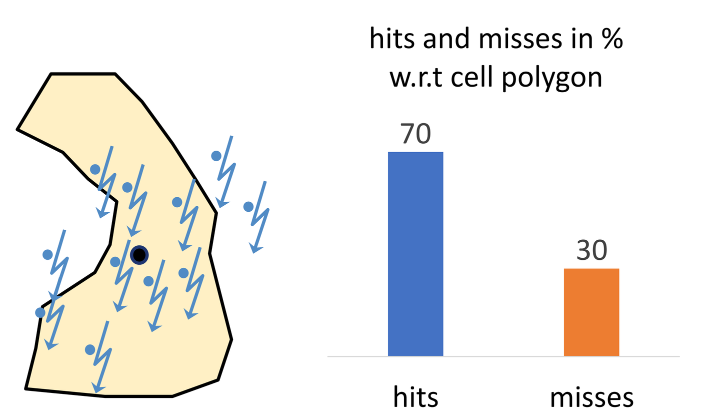


__Figure 1:__ Left: Cell polygon with centroid and lighting strokes. Right: 70% of the lightning strokes are located within a cell polygon, 30% are not.

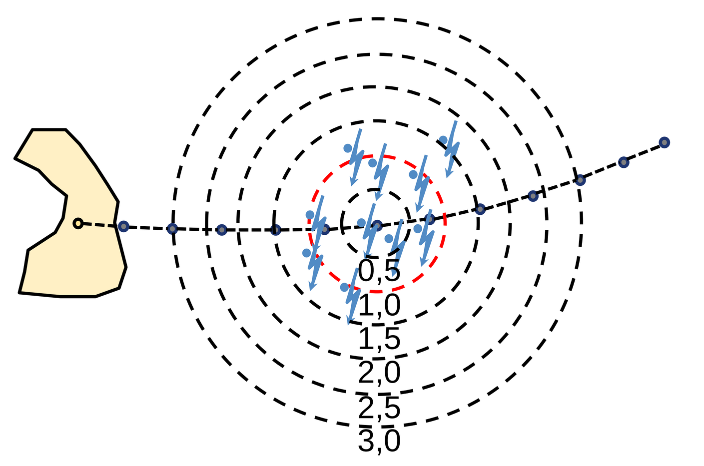
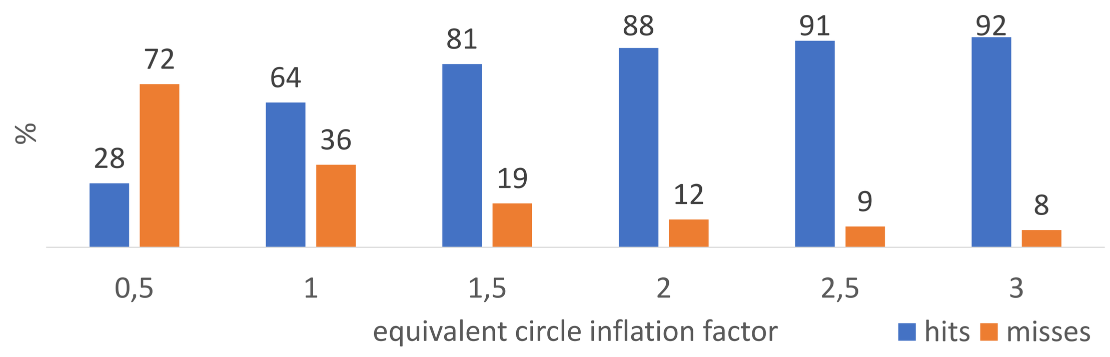


__Figure 2:__ Cell polygon and forecast centroids with surrounding circle of equivalent radius (red) plus inflated versions of it and lightning strokes at forecast minute 30.

Figure 3 shows hits and misses with respect to the circles around the **analyzed** centroid for different inflation factors. *Conclusion:* About 92% of the lightning strokes are located inside or in the vicinity of KONRAD3D cells.

__Figure 3:__ Hits and misses with respect to circles around analysis centroids. Inflation factor 1 refers to a circle with an area equal to the area of the cell polygon.



For inflation factor 1.5 and forecast steps up to 60 minutes, Figure 4 shows hits and misses. After 30 minutes about half of the lightning are still located inside or in the near vicinity of KONRAD3D cells.

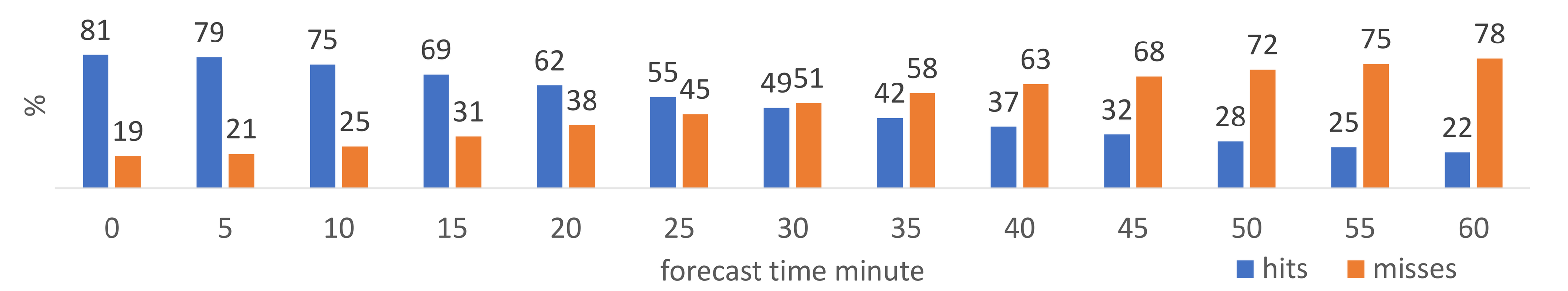


__Figure 4:__ Hits and misses for forecast times up to 60 minutes for a circle with cell equivalent area around forecast centroids inflated by a factor of 1.5.

Evaluation of uncertainty ellipses

Kalman-filter theory implies that our 1σ-forecast ellipses for t+x min. should contain about 39% of the centroids later analyzed at t+x. This can actually be confirmed in practice, see Figure 5. Thus, Kalman-filter tuning seems fairly appropriate.

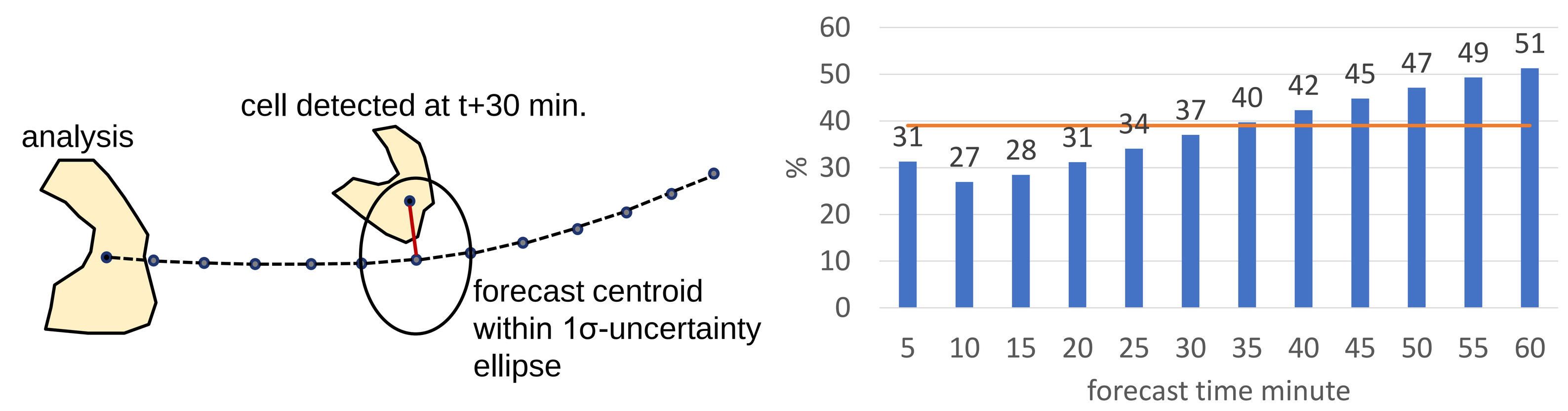


__Figure 5:__ Left: Analyzed cell with forecast centroids and a cell analyzed at t+30 min. with its centroid located within the uncertainty ellipse for t+30 generated at t+0. Right: Percentages of analyzed cell centroids that are located within the forecast ellipse for forecast time steps up to 60 min.. The orange line refers to the 1σ-barrier of ~39%.

Forecast centroids vs. analyzed centroids

Figure 6 shows how forecast centroids are distributed around future detections of the same cell.

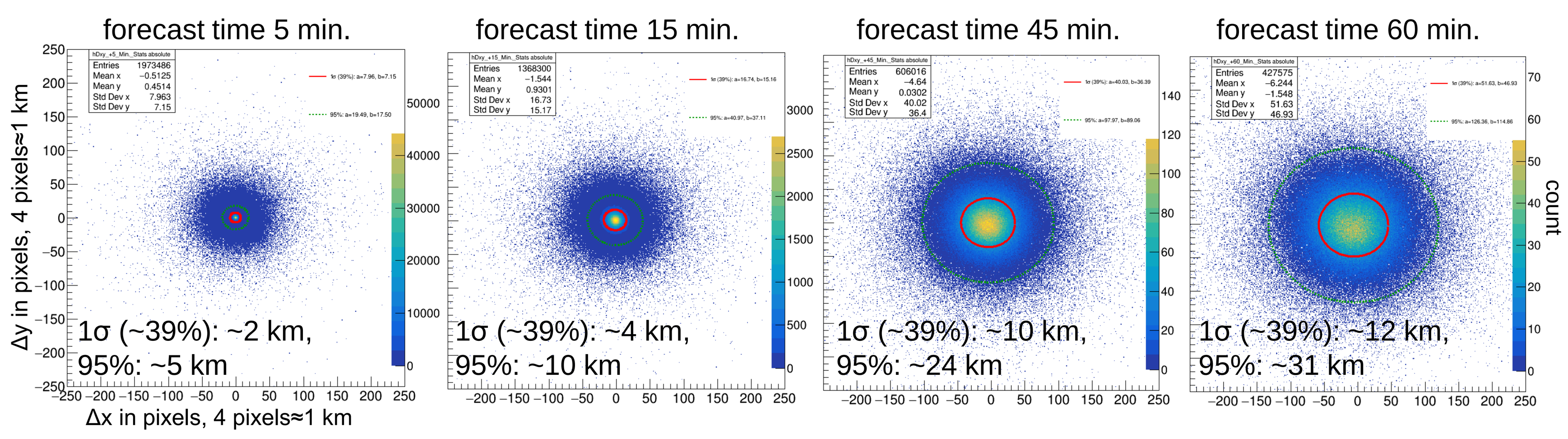


__Figure 6:__ Distribution of forecast centroids around analyzed centroids for +5, +15, +45 and +60 minutes forecast time. Red line represents 1σ-contour, green line represents 95% contour.

Track statistics

For a data subset of **LUMINA** from 01.03.2018 to 31.12.2022, we analyze cell tracks. Figure 7 shows the distribution of the maximum severity of the tracks. Figure 8 reveals about 21% of single-detection tracks without lightning and maximum severity *weak*. Moreover, Figures 9 and 10 demonstrate that, on average, tracks with maximum severity *extreme* last 75 minutes, whereas the maximum severity is first reached after 35 minutes. Hence, potential for nowcasting and timely warning exists!

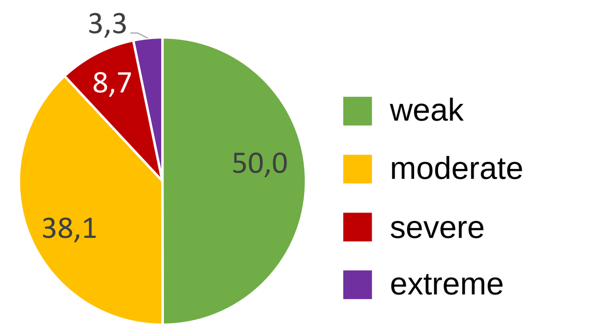


__Figure 7:__ Portions of tracks with __maximum__ severity weak, moderate, severe, or extreme.

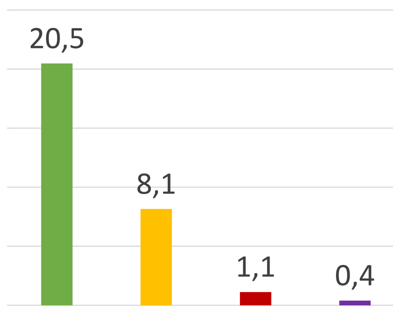


__Figure 8 (left):__ Percentage of tracks without lightning activity, length 1, and max. severity weak, moderate, severe, or extreme.

__Figure 10 (below):__ Frequency of number of time steps until severity extreme is reached (all tracks). Frequency for number of time steps=1 not shown due to contamination by split events).

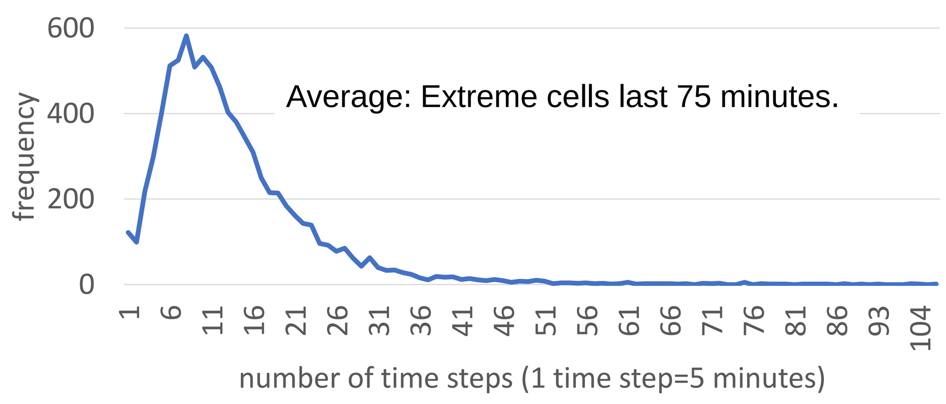
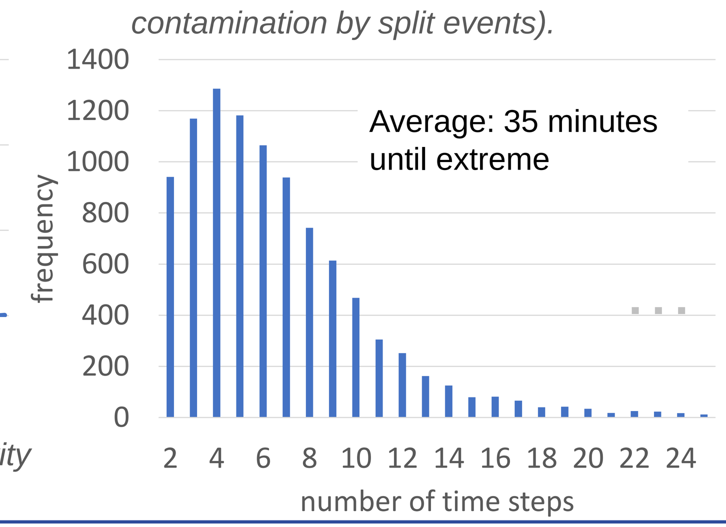


__Figure 9:__ Frequency of track lengths for tracks with lightning activity and maximum severity extreme (split tracks not regarded here).



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