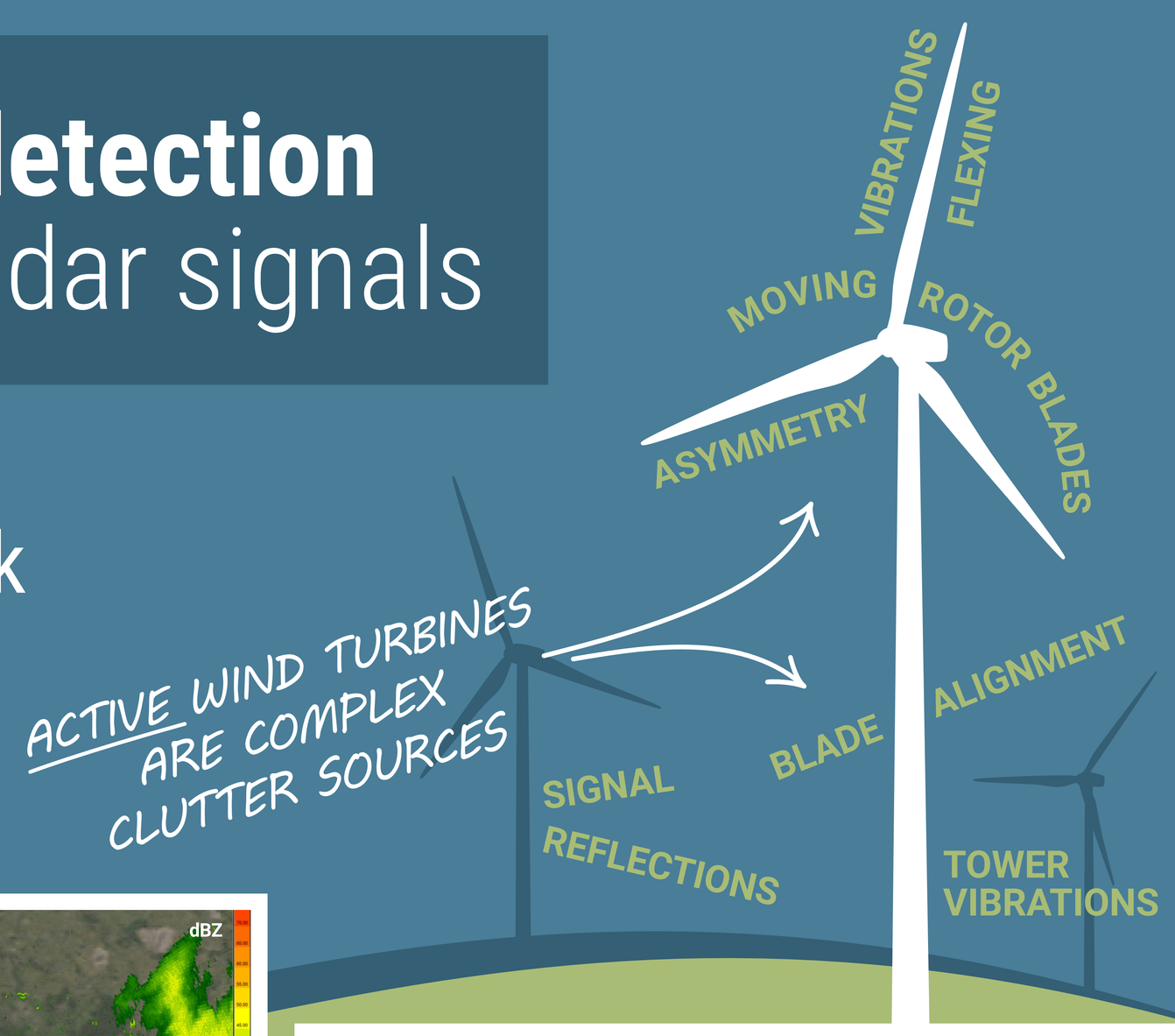
Wind turbine clutter detection
in real-time weather radar signals

Developments for the DWD C-band weather radar network



OBJECTIVE / DWD REQUIREMENTS

Weather radar is the only measuring method for area-wide and three-dimensional precipitation measurement.

Main tasks of DWD and other weather services (e.g. observing and forecasting the weather, issuing severe weather warnings) stand in the field of tension concerning renewable energy, especially wind turbines (WT).

Wind turbine clutter (WTC) is more complex than static clutter in radar data (see top-right illustration), so conventional clutter removal algorithms fail at detecting it.

Weather services must address this subject in order to assure reliable weather data and fulfil their main tasks.

Algorithm requirements for WTC detection in real-time weather radar signals from DWD radar systems:

- **Automatic and especially dynamic detection and flagging** of WTC at the radar signal processor level
- Executability on **existing hardware** (GAMIC ENIGMA IV)
- High detection probability and few false alarms for a **min. range of 15 km** (ideally >25 km) around the radar
- Optional automatic thresholding and confidence map

Status as of 08/2022:
GAMIC WTC detection algorithm active on all DWD C-band weather radar systems (last one since May 2021) to allow a detailed evaluation – flags are currently not applied.

ALGORITHM APPROACH

- Rotating blades and other WT characteristics (see top-right illustration) cause **irregular Doppler noise pattern**
- Wind turbines visible as point targets in the estimated noise (**NCP moment, Non-Coherent Power**)
- Strong fixed targets (e.g. power lines or towers) also cause peaks in NCP but due to phase-noise
- Differentiation with **CR moment (Clutter Ratio)**, generated by ENIGMA signal processor:
  - Wind turbine targets: small CR
  - Strong fixed targets: large CR

Implementation as a separate module, upstream of existing signal processing in ENIGMA:

1) Calculation and sorting of all FFTs
2) Estimation of NCP and CR moment
3) Identifying and flagging bins as WTC at local peaks
4) Expanding flagging along flanks of local peaks
5) Stabilising detections with a confidence map *(optional)*
6) Thresholding of WTC detections *(optional)*

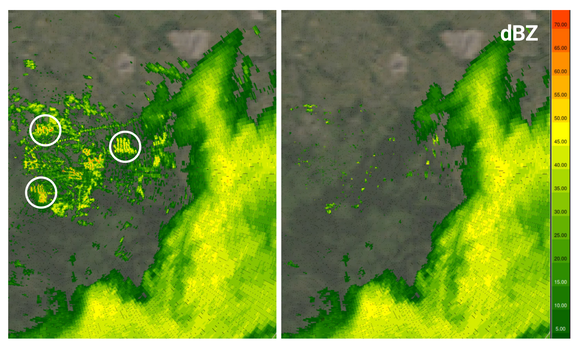


Fig. 1: Comparison of uncorrected reflectivity data with wind turbine clutter (WTC) encircled (left) and reflectivity data corrected for static clutter and WTC (right).

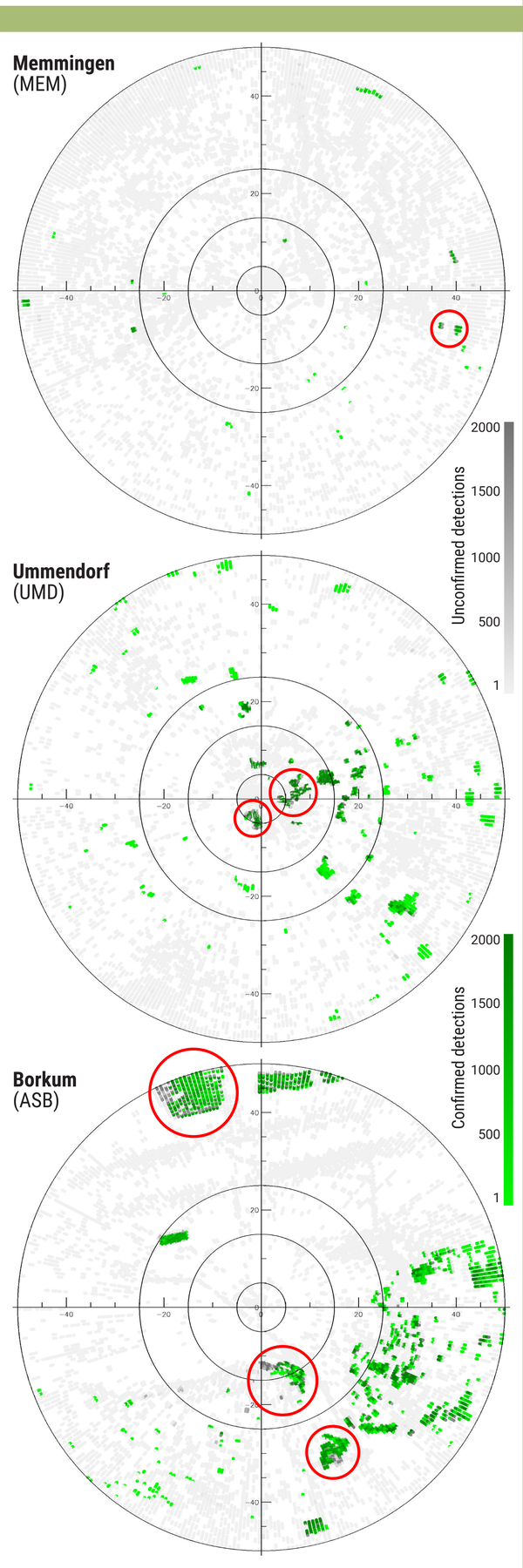


Fig. 2: Accumulations (7 days) of WTC detections (50 km range) from DWD radars with confirmed (green) and unconfirmed (gray) evaluation-database-entries (WT positions). Unconfirmed detections in red circles likely correct due to sphere of WT influence.

RESULTS & DISCUSSION

Comparison of WTC detections (without confidence map) with known WT positions from an evaluation database (data from Germany: Federal Agency for Cartography and Geodesy; data from neighbour countries and offshore regions: OpenStreetMap).

- First evaluation results (fig. 1 and 2) are promising, **the main requirements are satisfactorily met**
- **More than 75%** of WTC detections at confirmed WT positions
- Cumulative unconfirmed WTC detections close to known positions (see example red circles in fig. 2) are very likely correct detections due to **influence of WT on multiple neighbouring radar bins**.
- **Other possible reasons for unconfirmed WTC detections:** WT position not in evaluation database, side lobe effects, ships (moving corner reflectors), moving vegetation, weather
- The algorithm works at least **up to 50 km** (much more than requested distance of 15 km)
- Additional finding: **ship tracks visible** in accumulated WTC detection data (see straight lines in data from ASB)

General evaluation challenges:

- Evaluation database can be **incomplete or flawed** (WT not existing any more, under construction, not in database, false entries, ...)
- WT can be **switched off** (pitfall for WTC detection algorithm evaluation but conventional clutter algorithms will work)
- WT may be **"not seen" by the radar**
- **WT distribution** relevant (single turbines vs wind park)
- **Weather/propagation conditions** important
- **Sphere of WT influence** not taken into account in evaluation

OUTLOOK

- **Further analysis of unconfirmed WTC detections** (what were probable reasons)
- **Compare WTC detection data with and without confidence map** (the confidence map should eliminate temporary misdetections, e.g. due to moving vegetation or weather)
- Evaluation with data from **all DWD radars** and **longer time span**
- **A sophisticated correction algorithm** that goes beyond simple thresholding needs further research

gamic
WEATHER RADAR & SIGNAL PROCESSING

Matthias Toussaint, Dipl.-Ing. Simon Gerhards, Johannes Vieten
GAMIC GmbH
Weather Radar & Signal Processing
Roermonder Str. 151
52072 Aachen, Germany
info@gamic.com | www.gamic.com

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Dipl.-Ing. Patrick Tracksdorf (patrick.tracksdorf@dwd.de)
Deutscher Wetterdienst
Verfahrensentwicklung Fernerkundung (FE23)
Frankfurter Straße 135
63067 Offenbach am Main, Germany
www.dwd.de

Download the poster