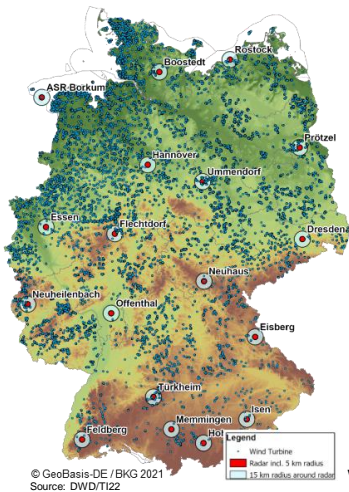# Monitoring and quantifying the influence of wind turbine clutter in weather radar data

Michael Frech, Maximilian Schaper, Annette Böhm, David Scholz
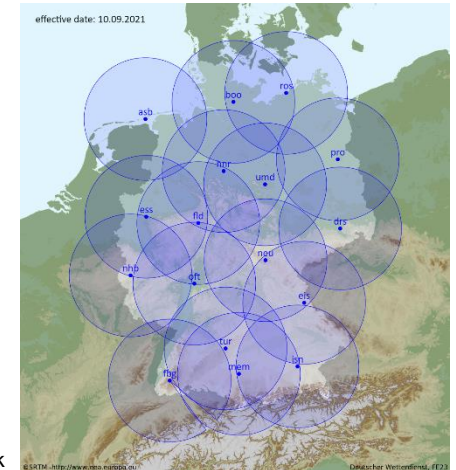DWD, Meteorological Observatory Hohenpeißenberg

part panorama seen from the radar system Ummendorf (UMD), photo DWD/TI33

wind turbines (blue dots)

DWD C-Band weather radar network

- Motivation
- Dynamic wind turbine clutter detection: Principle & Implentation
- Monitoring set up
- Some results
- Summary

radar Borkum

Wind turbine situation in Germany
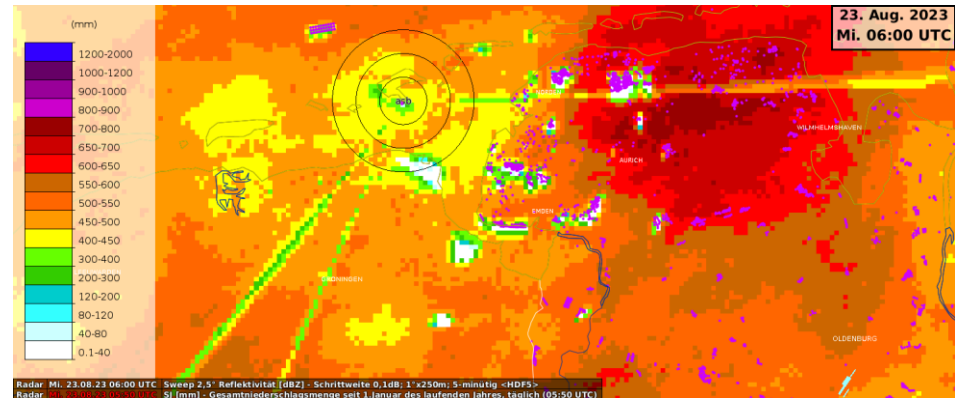
➔ The political situation since 24 February 2022 and the following energy crises in Germany forced DWD to allow wind turbines in the 5-15 km area. This was laid out in a Government action paper in April 2022.

➔ Targets of the Government:

  ➔ speed-up of the approval procedure

  ➔ planning reliability

  ➔ open up previoulsy restricted areas for wind energy projects

➔ 5 km – radius supposed to be protected.

So far the 5 km radius is not challenged. However, since there is no legal protection, a future challenge cannot be ruled out!

Consequences

➔ Prepare for a challenge of the 5 km radius (not a topic in this presentation)

➔ Monitoring of the wind turbine clutter (WTC) situation throughout the radar network

Monitoring goals:

▪ Continuious monitoring of WTC in the 0 – 15 km range

▪ Further quantifying the effect of WTC on radar data

▪ Observing possible trends - gathering a solid basis for possible legal actions

▪ Improving the WTC identifcation algorithm and supporting the work for mitigation algorithms

 In 2023: so far 20 new wind turbine sites in the 5 – 15 km radius nation wide

Dynamic wind turbine clutter detection

- Algorithm developed by GAMIC; presented at the WXRCalmon 2021
- Implemented and in operation in the DWD radar network since Summer 2021

Each hdf5/ODIM multi-moment single sweep now contains:
- WTC quality mask (WTC found yes/no)
- New radar moments quantifying the WTC

Basic algorithm

- Rotating blades cause elevated noise floor in Doppler spectrum (tangential velocity of blades)

- Wind turbines visible as point targets in the estimated noise **NCP (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 (Clutter Ratio)** moment, computed by *ENIGMA* signal processor:

Small for wind turbine targets

Large for strong fixed targets

From the GAMIC/DWD presentation at the WXRCalMon in Toulouse 2021
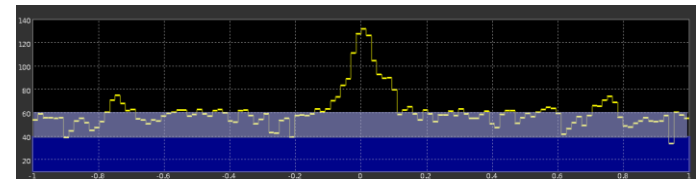
Doppler spectra with elevated noise level

Monitoring set up

- Whenever a WTC flag is detected: extract moments from corresponding range bin,
- All information is stored in an InfluxDB data base
- Only using the pcp-scan and shallow vol-scan elevations: 0.5° – 5.5°
- Data collection is ongoing since the beginning of 2023

- Plan to set up a Grafana dashboard to continously monitor results

In this presentation:

Initial evaluation in order to find evaluation metrics

WTC anlysis UMD

As of 2022:

224 wind turbines in 0 -15 km radius
54   wind turbines in 5 km radius.

Good test candidate to test the WTC detection algorithm

Definition:
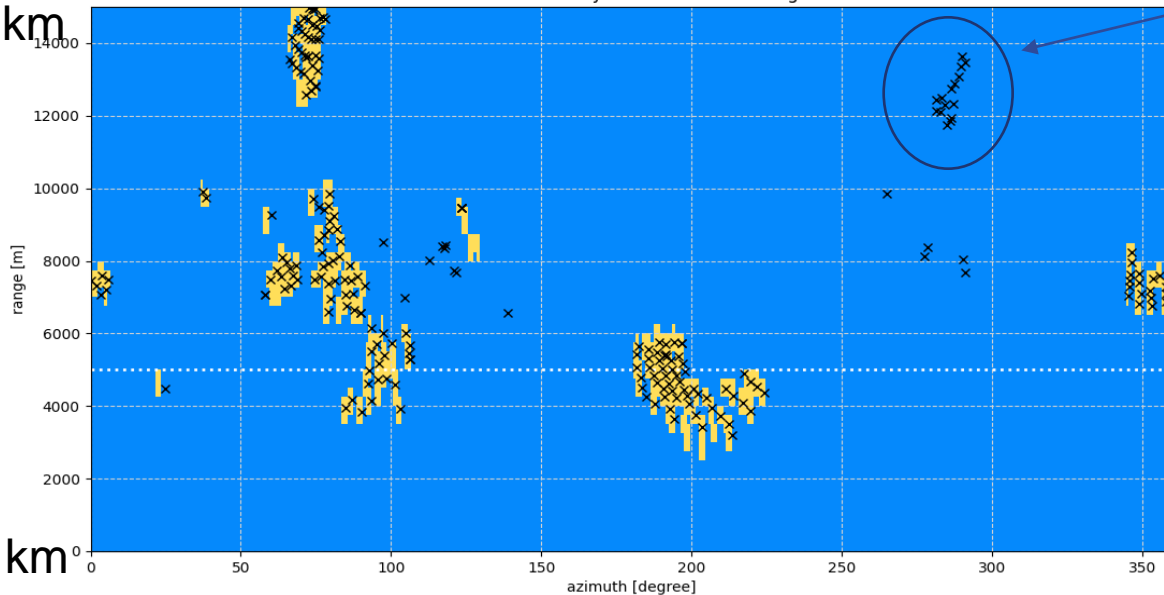**„WTC severity"** of 1: WTC is detected 100% of the time at a given range and time interval
We consider a WTC severity of > 0.5 as a persistent WTC signal

It is expected that WTC severity is always < 1 due to wind turbine operation & wind conditions

WTC UMD & wind turbine locations

WTC severity > 0.5

Favorable orography

umd - bins with "severity" >= 0.5 - within range 0-15km

15 km

0 km

0°

360°

data:1.6. – 20.6.2023

Essentially same results taking s > 0:
WTC presence most of the time

Rangebin resolution 250 m

data:1.6. – 20.6.2023

data:1.4. – 20.4.2023

15 km

0 km

0°   360°

WTC severity > 0

0.8

0
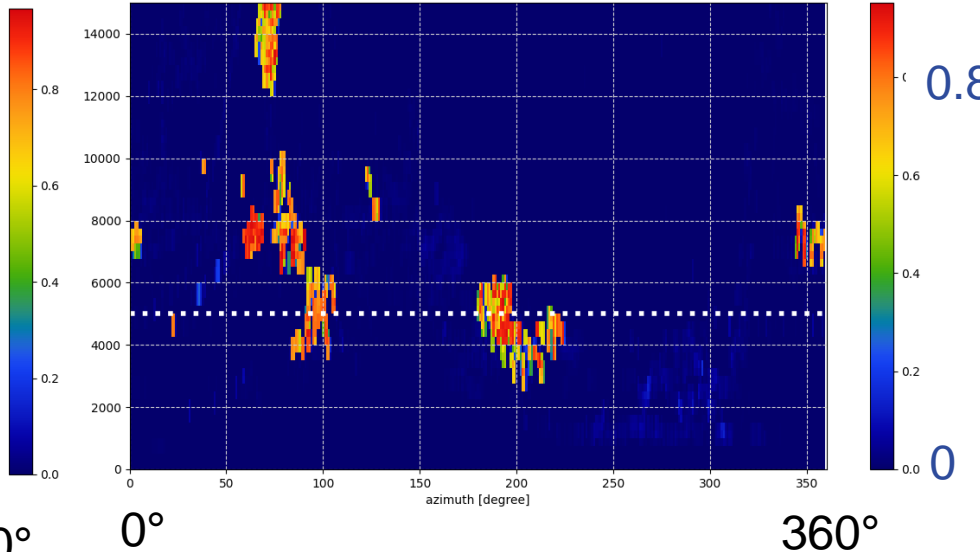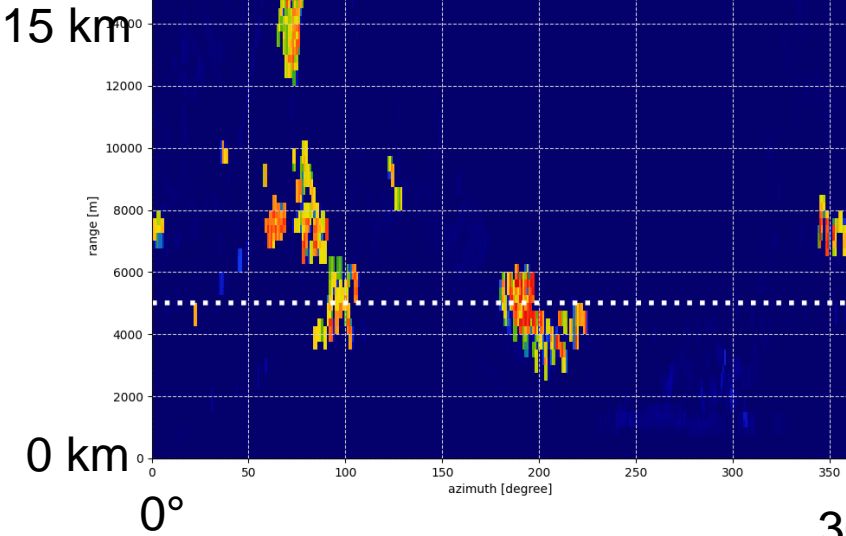
0°   360°

Small number of false detections
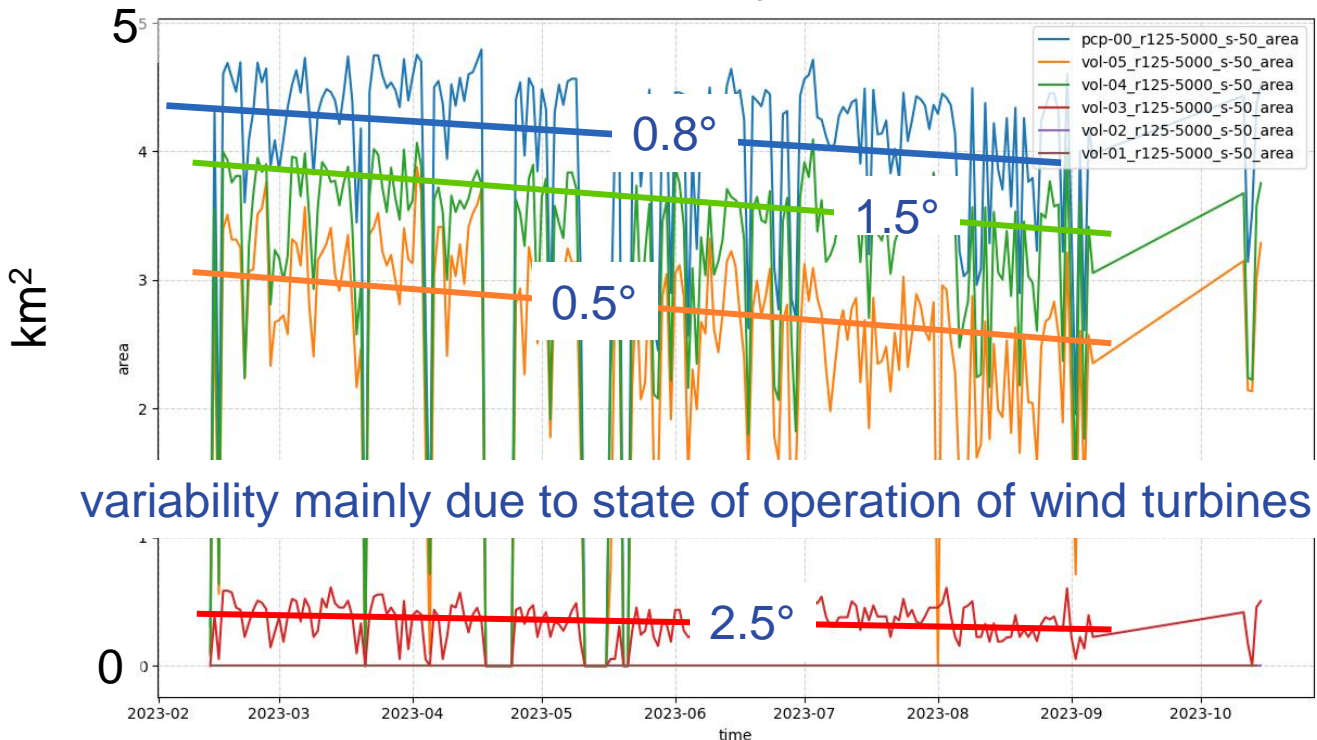
the two periods show consistent results

WTC UMD and occupied area: time series

WTC severity > 0.5

Range 0-5 km

0.8°

1.5°

0.5°

variability mainly due to state of operation of wind turbines

2.5°

February 23

October 23

Vol01= 4.5°
Vol02= 3.5°
Vol03= 2.5°
Vol04= 1.5°
Vol05= 0.5°
Pcp ~ 0.8°

WTC visible up to 2.5°

5% of area occupied with WTC

WTC UMD and occupied area: time series

February 23
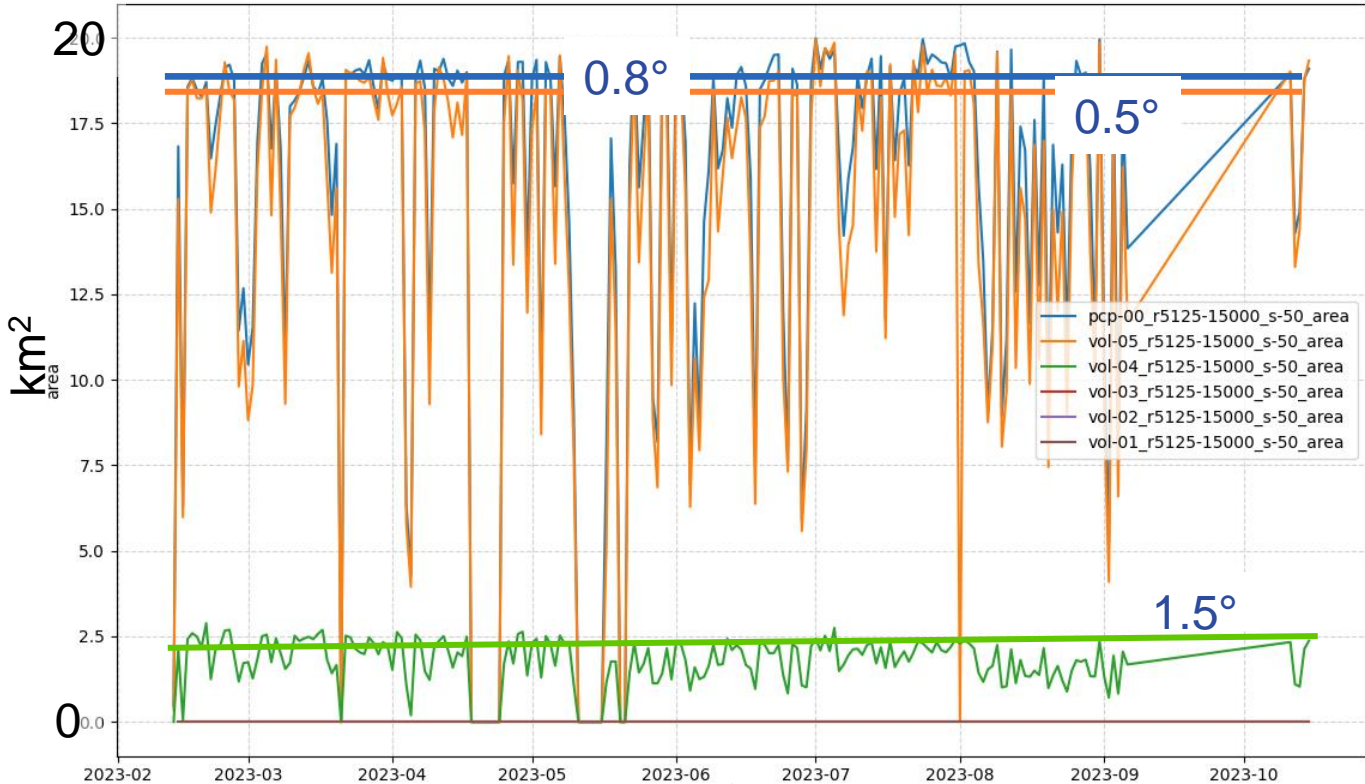
October 23

Range 5-15 km

Vol01= 4.5°
Vol02= 3.5°
Vol03= 2.5°
Vol04= 1.5°
Vol05= 0.5°
Pcp ~ 0.8°

WTC visible up to 1.5°

3% of area occupied with WTC
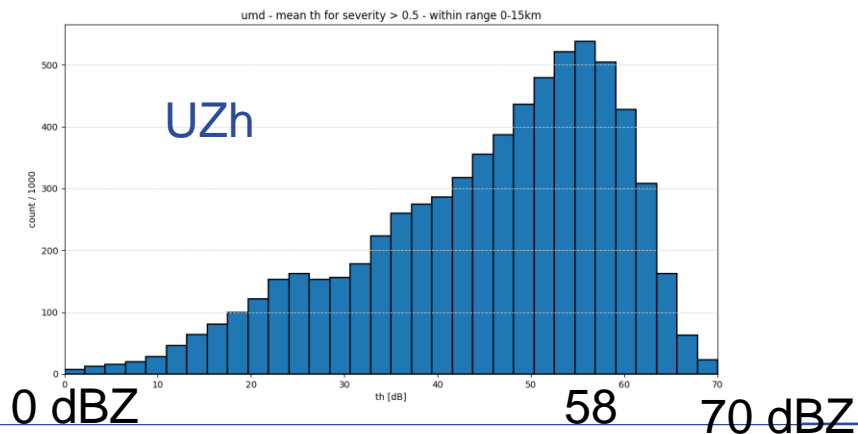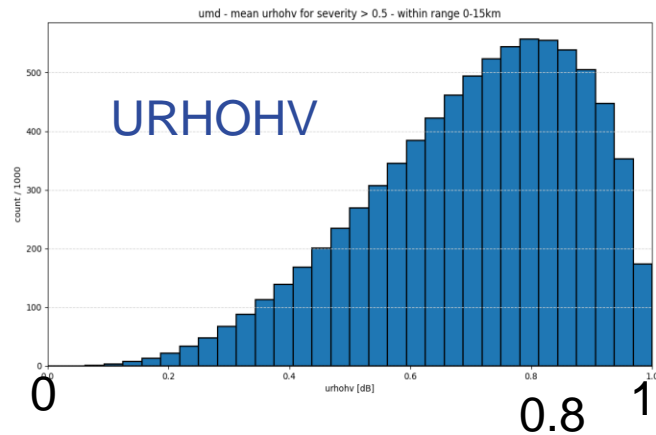
WTC severity UMD and occupied area: time series

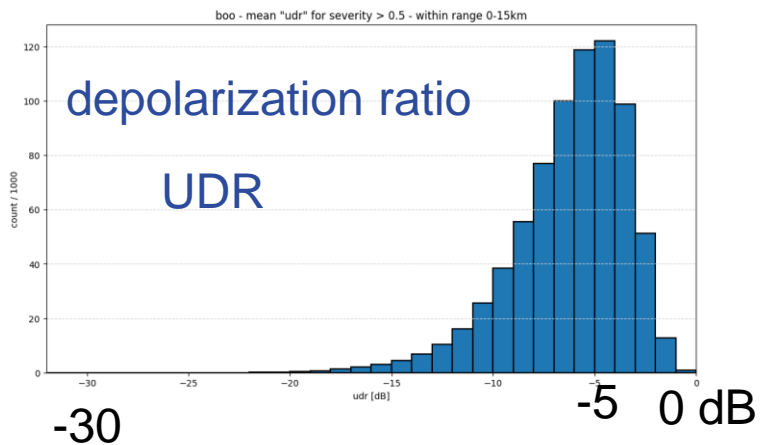**Some observations:**

- Within 5 km: elevation up to 2.5° is affected; about 5% of area (~ 4.5 km^2)
- Within 5-15 km: elevation up to 1.5° is affected, about 3% of area (~18 km^2)

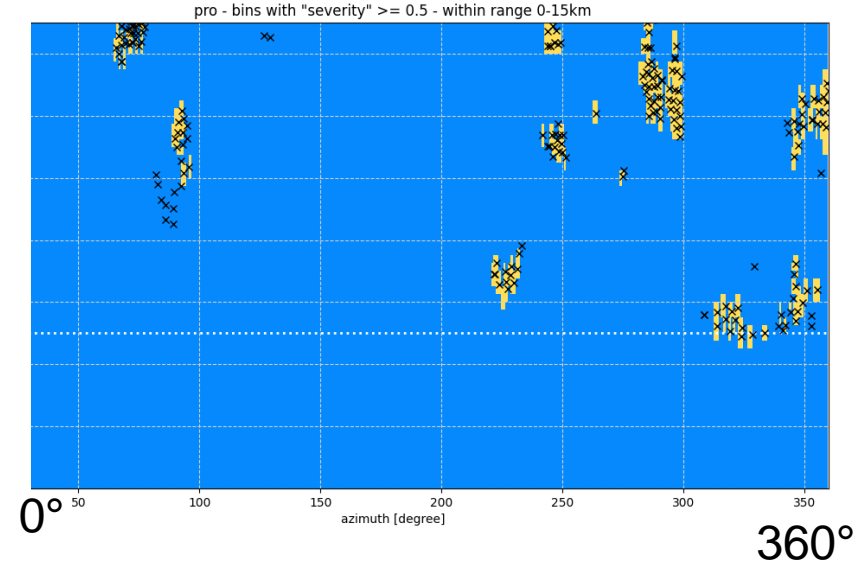Temporal variability due to operational status of wind turbine & wind conditions.

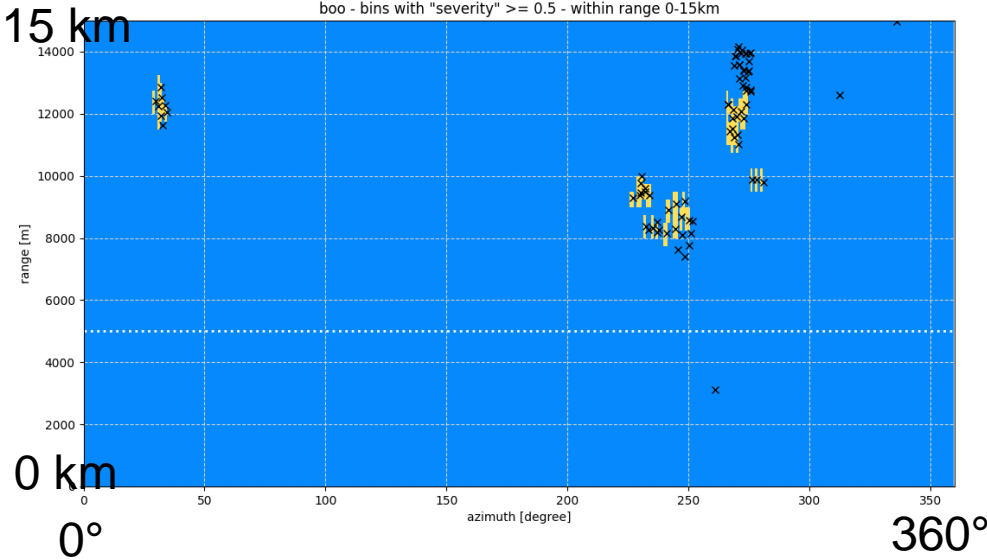# Some radar moments with WTC

depolarization ratio

UDR

-30   -5   0 dB

URHOHV

0   0.8   1

UZh

0 dBZ   58   70 dBZ

Other sites (examples):

DWD
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

WTC and wind turbine locations

Boostedt

Prötzel

15 km

0 km

0°   360°

0°   360°

WTC clutter detection proves to be robust

Summary

- Monitoring the wind turbine clutter in the DWD radar network has been established.
- Dynamic detection of WTC works well
- Radar UMD, in 5 km radius: elevation up to 2.5° affected by WTC
- Radar UMD, 5-15 km: elevation up to 1.5° affected by WTC
- So far only a small number of new wind turbines in 2023 (within 5-15 km); no visible signal in the time series.
- Continuous monitoring: continuous quantification of the WTC problem.