RC4: 'Reply on RC3', Norman Donaldson, 10 Dec 2025

Reply: We thank the reviewer for his very careful review of our manuscript! The comments and suggestion were considered and we think they improved the clarity or our paper.

Review of "Monitoring and quantifying wind turbine clutter in DWD weather radar measurements"
Author(s): Michael Frech et al. (michael.frech@dwd.de)
MS No.: egusphere-2025-4957
Reviewer: Norman Donaldson, Environment and Climate Change Canada (Ret'd)

Overall Quality

The overall quality is very good. I see no serious issues with methodology and the methodology is novel enough to deserve publication. The work itself documents in some detail how wind farms impact radar measurements, both traditional (reflectivity and Doppler velocity) and dual polarimetric, which is important for other weather radar users. My only qualification to that is the section on blockage, which I would describe as "indicative" rather than conclusive. Trying to assess blockage by wind farms is exceedingly difficult. This is possibly the best attempt I have seen, even if not conclusive, so it should be presented. I recommend publication after the authors consider my comments below. I would characterize the changes as minor.

Content Comments

- **Radars:** Please give more description of the TUR and UMM radars: latitude ,longitude, height of antenna ('horn height"), resolution of radar bins (1° x 250m?). Frech (2017) gives other specifics like antenna size and wavelength but that could be repeated. Possibly a small table.
    - **Response:** We have added two tables with information on the radar locations Türkheim and Ummendorf and the WT location TUR2 and TUR3.

- **Line 4:** "There are currently no filter methods that can reliably separate wind turbine clutter from desired weather information." This is true for operational radar sampling, but I think there are techniques that do work with IQ data using a very large number of samples.

- **Response:** There is some research out there (e.g. S. Torres presented a possible filter approach at ERAD2024 and the AMS radar conference in 2023), but those are so far not usable for operational applications; the results look promising, but only have been shown for case studies; commercially available signal processors do not come with WT filters. We aim at the development of a filter within the WICLEAN project (see conclusions). We added that there is no filter available "for operational weather radars"

- **Line 15:** “traditional radar reflectivity.” What does the word “traditional” mean here?
  - **Response:** We removed "traditional".

- **Line 16:** Maybe start new paragraph for the blockage discussion?
  - **Response:** A new paragraph is included. This makes sense.

- **Line 94:** You point out that NCP does not isolate WTC from other static clutter sources so it is unsuitable by itself. Operationally, we want to identify all clutter. Why is there a focus on only finding wind turbines specifically? Is that for research/regulatory purposes or is there an operational reason to distinguish WTC from other clutter?
  - **Response:** There is primarily an operational reason. A proper classification (and quantification) of the clutter type is an requirement from developers that are responsible for radar based products, but also from forecasters (helps them to better interpret radar images). Another reason comes from agreements we have with some wind parks: they are supposed to shut down operation, if severe weather is in the pipeline which we do not want to miss with our radars. So far this option hasn't been used but we should be able to verify the proper shutdown of a wind park in such situations.

- **Line 100:** Turbines are fairly isolated in range. Less so in azimuth. The method seems to be using only range isolation. This is subject to the further qualification that the tower/mast is very isolated in range, but if a turbine is facing normal to the radar radial, the blades extend up to 100m along the radial in each direction. I see that the detection algorithm is reporting values in front of turbines in Figure 3 and 8. Is that an artefact of the algorithm or is it real detection of blades when they pointing toward the radar?
  - **Response:** Thank you for your comment. Yes, you are correct: the method uses only one "ray" at a time. The fact that you also see detections in front of the turbines is due to step 5 of the method described in chapter 2.1: "Each local maximum found in this way is further extended so that all (25 m) range gates up to the previous and thefollowing minimum are marked.". This "extension" works on the "25 m range gates" (oversampling) which afterwards are getting combined to the final output "radial range resolution" (e.g.: the "250 m final output range resolution" is composed of ten "25 m range gates"). There, one

marked "25 m range gate" is sufficient to mark the whole final output "250 m range gate". So, it is by design, to be on the safe side.

- **Line 105:** Later it seems that CR is used only for the H channel. Specify that here?
  - **Response:** Thank you for your comment. You are correct regarding the detection algorithm (Chapter 2.1). We changed the text to be more precisely. In general: The estimation of CR runs for both polarizations independently. Throughout the paper, we show primarily results from the horizontal channel, as the results from the vertical channel are very similar.

- **Line 127**: It is not explicitly stated how the naselle elevation of 1.0° was calculated. I assume the di□erence in terrain height (about 70m) is included. A quick look suggests that the bottom of the masts could be hidden by intermediate terrain and forest. By the "height of the mast" I assume it is meant the height of the rotor axis. (Ie the total height of blade tip at its highest should be mast + naselle + blades).
  - **Response:** Your interpretation is correct.

- **Figure 3:** The colour bar does not correspond to the figure. The colour bar shows pure grays, but the figure is using colours with a magenta/purple shade. The figure is deceptive because it implies the radar antenna is higher than all surrounding terrain. Google Earth says the ground height is about 800m at turbines TUR2 and TUR3, and the height at the radar is about 735m. That means the antenna would need to be at 65m above ground to equal the ground height at the turbines. Maybe the radar is that tall?! <See comment about providing details of the radar siting.>
  - **Response:** Thanks a lot for pointing this out! You are correct: antenna center height is 767,62 m, the total height of those wind turbines is about 1022 m (with respect to sea level); the height of the topography is 788 m. We accidentally limited the plotted range between -200 and 0 m, we now plot terrain height in a range between -200 and 100 m.

- **Regarding Figure 3:** Maybe add "The proposed detection method has highlighted two wind turbines at 12.4 km, 56.8° which were missing from our turbine database." At coordinates (48.646°, 9.924°) there is a pair of turbines visible in Google Earth. The figure has no X's there. <<After writing this I saw the discussion around Line 172. Move that to here?>>
  - **Response:** In figure 8 we plot in addition the wind turbine location based on the satellite product and discuss the problem with up-to-date and correct data from the federal states. The two wind turbines you point out are actually detected in the satellite product. However the two new wind turbines we investigate are not. The reason for this is simple: the product we use here was generated before the wind turbines were built. We are currently working on establishing an operational service of updated wind turbine locations every half year.

- **Figure 3:** Is it my imagination or are there different intensities of yellow used for the detections? At farms where I would expect to be the worst WTC the colours seem to be
  brighter yellow.
  - **Response:** There is no color scale for the wind turbine clutter (WTC) detections. Once we find a WTC in more than 50% of the cases the corresponding rangebin is colored in yellow. Figure 9 shows an example where the WTC persistence in a range between 0 and 1 is shown.

- **Figure 3:** It is not stated what elevation angle this data is from. Terrain following?
  - **Response:** This shows the persistent WTC at an elevation of 0.5°. We have added this information into the caption.

- **Line 145:** Mention in main text that this from only one of the two turbines?
  - **Response:** Added that the 2-distributions are derived from TUR3 (one of the two wind turbines). Thanks for the hint.

- **Figure 4** Change “wea” in title? Is it easy to replace the WIGOS id with a name. FYI I could not find this ID in the OSCAR database, but I have little experience with WIGOS, so it might be somewhere else.
  - **Response:** Thank you for your comment. Concerning the WIGOS-ID: Yes, you are correct. The WIGOS-ID was assigned internally (0-276 DE) and is (so far) not useful outside DWD. We removed it therefore.
    wea is now replaced by "WT" (wind turbine).

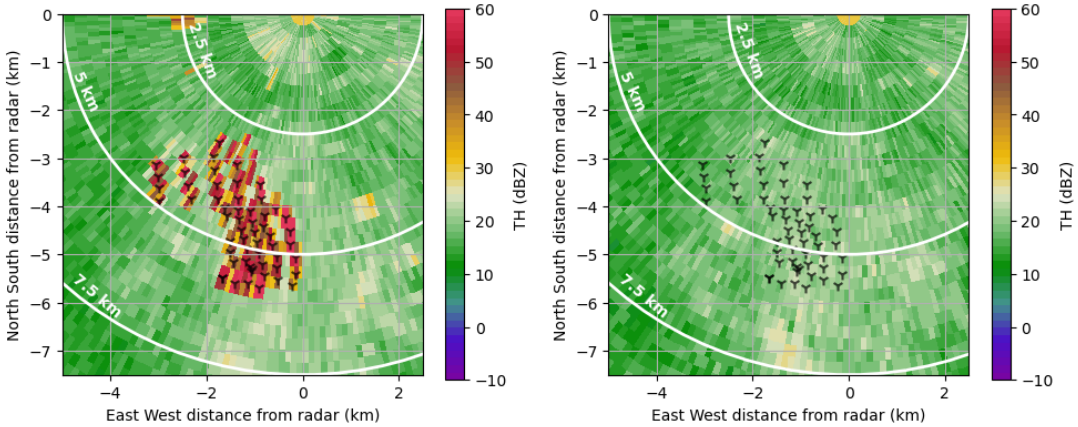
- Figure 8: As with Figure 3, colour bar does not correspond to the figure itself.
  - **Response**: See response concerning figure 3 above.

- **Figure 8** and **Line 195:** A better example of bad coordinates from the state database might be the echoes at 127°, 8.6km
  - **Response:** Could be taken as well. In general we want to make the point, that there are quality issues with wind turbine locations from the official data bases, so we are quite happy that there is this satellite based source which can provide consistent WT locations across federal states and countries.

- **Figure 8:** crosses are red not black.
  - Response: corrected

- **Figure 8**: Comment: radar elevation angle of ground height using standard propagation might be better than simple height …. if it easily created. (Same for Fig 3.)
    - **Response**: We are working on a follow-up paper (where we look into the correlation of WTC and WT operation data in more detail) where we consider you suggestion. For now we want to keep the plot as is.

- **Figure 10:** In my opinion the upper limit on reflectivity colours should be higher. I was surprised that the turbines seemed to be spread uniformly across 3°, until I realized that the observed values were far above the colour limits; colours were saturated so no detail below 3° in azimuth. I suspect the reported reflectivities are in excess of 50 or 60 dBZ. (This links back to the remarks around line 45 but isn't really a topic for discussion in the paper.)
    - **Response**: You are correct, the colours are saturated at the location of the wind turbines. Setting the range of the color bar to a range of -10dBZ to 60 dBZ (see plot below) shows this. The point that we want to convey with this figure is to show how the bins surrounding the wind farm are or aren't affected by the turbines, not so much the impact at the location of the turbines itself. Hence, we opted to use a narrower color bar range to focus on more subtle differences. Figure 13 actually contains data from the exact same time with an extended colorbar.



- **Figure 11:** What is the meaning of white? I can guess that clutter has exceeded the ability to correct reflectivity, but please state meaning. The same comment for Figure 12
    - **Response**: Those are rangebins that are threshold using an SQI threshold of 0.25. This is mentioned now in the caption.

- **Line 235:** "At 3.5° elevation, the wind farm has a larger e□ect on the spectral width." Larger than what? At first I though this mean larger than 1.5deg, but I assume it means larger than VRADH. (Regard Fig 11)

- **Response**: We have reformulated the sentence. The wind farm has an clear effect on the spectral width if you compare the corresponding rangebins with the surrounding range bins where no possible wind turbine effect is seen.

- **Figure 12**: Maybe comment on the red areas within the wind farm. The QC has not caught these area.
  - **Response**: Good point. However, we prefer not to go into the details on the DWD radar data quality details here. The purpose of this section is to provide a qualitative impression of the impact of this wind farm leading over to an analysis of beam blockage.

- **Figure 14**: What is "Wea" and "NoWea" on the figures? Maybe "WF" (Wind Farm) was intended, since discussion in the text indicates that the "Wea" distributions are from the wind farm sector. (Elsewhere WEA is WTC?)
  - **Response**: We have changed this in the figure.

- **Blockage section**:

  This is probably the best attempt to quantify blockage by a wind farm that I have ever seen. However, I still think it is indicative rather than conclusive. There seems to be a lot of variability/noise in the distribution. Doing a good statistical estimate of the uncertainty in the estimates is not easy. The only thing I'd suggest is trying to break the dataset in two (say by year) and comparing results from the two subsets. Another potential objection is the assumption about the di erence between data at 3.5 km and 6.5km being due only to the wind farm. Is there any possibility that surface targets have di erentially contaminated the data? For example, there is a forest at 6.5km in one sector but not the other. One might worry that the hill under the wind farm has blocked some signal. The reviewer is almost certain that the hill is not an issue, but this should be stated. (The reviewer had exactly that potential situation. A look at data before a wind farm installation shows same the partial signal reduction we thought the wind farm caused.) I am not saying these things are real issues, but they could be, even if I suspect they are not. I think the blockage section should remain despite my concerns, but if the authors have any responses they should please add them.

  It would be useful for context to give some information about the turbines in the blockage assessment (hub height, blade diameter, mast diameter). One might add that the hubs are quite close to the middle of a beam at an elevation of 1.5° (reviewer assumed 100m mast) while the tips are at an elevation of about 2.3° when vertical and thus outside the nominal size of a 0.9° beam at 3.5° elevation (reviewer assumed 100m mast with 106m blades).
  - **Response**:
    - Added a comment about the turbines in the windpark towards the southwest of UMD: "The wind park consists of 57 wind turbines, with rather small turbines. The median nacelle height of these turbines is 70 meters, the median rotor diameter is 60 meters."

- Added a comment about the robustness of the results: "We tested the robustness of the results by computing the reflectivity differences for various subsets of the data, stratifying it for example by year or by radar reflectivity mean values. The absolute numbers of the results vary based on the selection of the data. However, in all cases, the reflectivity differences at 3.5° elevation were very similar for both sectors, and there was always a clear difference of at least 0.3 dB between the two sectors at 1.5° elevation."
- A panoramic view from radar Ummendorf towards the south shows the relatively flat terrain, with no significant differences in terrain height in the two sectors used for the beam blockage analysis.

- **Line 331:** “The beam blockage results clearly suggest, that wind turbine development in the 5 km radius must be avoided”. My interpretation of the result is a bit more conservative, so I might delete “clearly”. - No comma in this sentence.
  - **Response**: we removed the "clearly". There remains to be a strong statement ("must"), which we want to make here.

Technical glitches:

- **Throughout**: should “WEA” be “WTC” (German to English for wind turbine clutter) except maybe “WF” where an entire wind farm seems to be indicated.
  - **Response**: Thank you very much. The abbreviation "WEA" stands for the German word "Windenergieanlage" (wind turbine) and is unintentionally used in two places in the text. We have corrected these two instances and replaced the abbreviation "WEA" (RC1 had also pointed this out to us.).

- **Style**: I would write text like “depolarization ratio DR” with commas, such as “depolarization ratio, DR,” but I know there is not consensus on this.
  - **Response**: Thank you for your comment. We changed lines 214, 308 and related line 212.

- **In several places** “rangebin” -> “range bin”
  - **Response**: Thank you very much. We have corrected that (RC1 had also pointed this out to us.).

- **Line 10** “WT” is not separately defined although it can be inferred from “WTC”.
    - **Response**: Thank you for your comment. We introduced "WT" with "wind turbine (WT)" in the abstract on line 12 (RC1 had also pointed this out to us.).

- **Line 141** A list of variable abbreviations is given. These are not defined until later in the paper.
    - **Response**: Thank you very much for this comment. We added the appropriate definition and additionally defined "uncorrected" to be more precise here (RC1 had also pointed this out to us.).

- **Figure 5**: It would be more visually pleasing if the frame on right were the same size as the frame on left. (Unimportant.)
    - **Response**: we keep it as it is.

- **Line 253** “extend” => “extent”
    - **Response**: Thank you for your comment. We corrected that.

- **Line 219** “DR” has been defined, but “UDR” appears without definition.
    - **Response**: Thank you for your comment. We have corrected this in accordance with the comment "Line 141" above.

- **Line 266** “since we do exclude” -> “since we exclude” (Using “do” is slightly aggressive, it suggests an emphatic response to someone who suggested that you did not exclude.)
    - **Response**: Thank you for your comment. We adopted that.

- **Line 267** and several other places, “ZH” and “Zh” are used but TH would be more consistent.
    - **Response**: Thank you very much for Your comment. ZH is incorrectly used here. It should be TH. We changed the text accordingly and added "uncorrected" to be more precise here. We considered adding "uncorrected" to the other text passages in Chapter 4, but decided against it for the sake of readability. (RC1 had also pointed this out to us.)

- **Line 273** “(1.4 – 30.0)”. What does this mean?
    - **Response**: Thank you very much for Your comment. This should be dates giving the beginning and the end of the warm season. We have corrected that.

- **Line 310** “WT disturbance of DR”. I would say “on” rather than “of”. Not important.
    - **Response**: Thank you for your comment. We adopted that.

- **Line 343** The word “ombrometer” is rarely used, so I suggest “rain gauge”. I even suspect that a quarter of readers will not know the word.
    - **Response**: Thank you for your comment. We adopted that.

- **Figure 10**: FYI there are four turbines in the north of the wind farm where there are turbine echoes but no crosses. Look near (52.1306N, 11.1613E)\
    - **Response**: As noted in comment to figure 8 we have the problem with up-to-date and correct data from the federal states with respect to wind turbine location. The three wind turbines you point out are actually detected by the satellite product. We are currently working on establishing an operational service of updated wind turbine locations every half year. For now we keep the figure as it is as this is the official data based from the federal state. There the overall impact of wind turbines on the radar data can be nicely demonstrated and discussed with these plots.