Review of "Monitoring and quantifying wind turbine clutter in DWD weather radar measurements"

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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.

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.

Line 15 "traditional radar reflectivity." What does the word "traditional" mean here?

Line 16: Maybe start new paragraph for the blockage discussion?

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?

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?

Line 105 Later it seems that CR is used only for the H channel. Specify that here?

Line 127. It is not explicitly stated how the naselle elevation of 1.0° was calculated. I assume the difference 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).

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.>

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?>>**

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.

Figure 3: It is not stated what elevation angle this data is from. Terrain following?

Line 145: Mention in main text that this from only one of the two turbines?

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.

Figure 8: As with Figure 3, colour bar does not correspond to the figure itself.

Figure 8 and Line 195 A better example of bad coordinates from the state database might be the echoes at 127°, 8.6km

Figure 8: crosses are red not black.

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.)

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.)

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

Line 235 "At 3.5° elevation, the wind farm has a larger effect 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)

Figure 12: Maybe comment on the red areas within the wind farm. The QC has not caught these area.

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?)

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 difference between data at 3.5 km and 6.5km being due only to the wind farm. Is there any possibility that surface targets have differentially 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).

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.

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.

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.

In several places "rangebin" -> "range bin"

Line 10 "WT" is not separately defined although it can be inferred from "WTC".

Line 141 A list of variable abbreviations is given. These are not defined until later in the paper.

Figure 5: It would be more visually pleasing if the frame on right were the same size as the frame on left. (Unimportant.)

Line 253 "extend" => "extent"

Line 219 "DR" has been defined, but "UDR" appears without definition.

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.)

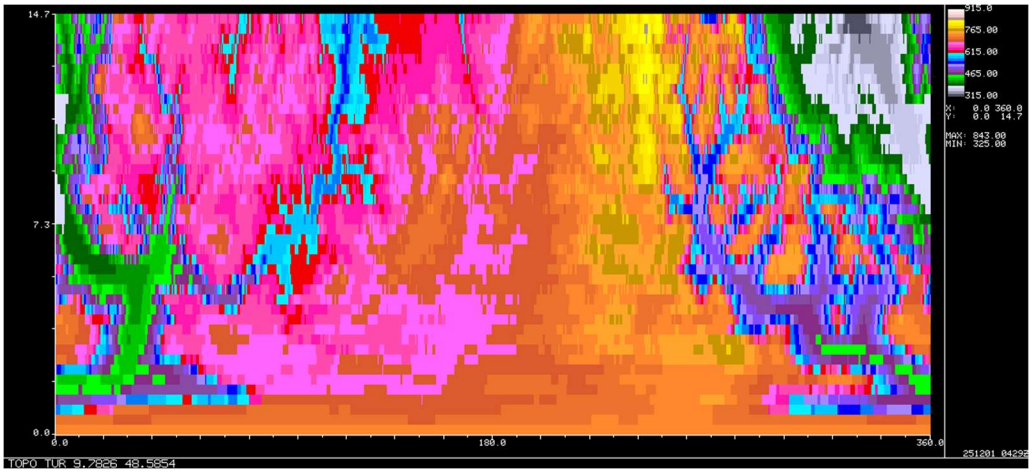
Line 267 and several other places, “ZH” and “Zh” are used but TH would be more consistent.

Line 273 “(1.4 – 30.0)”. What does this mean?

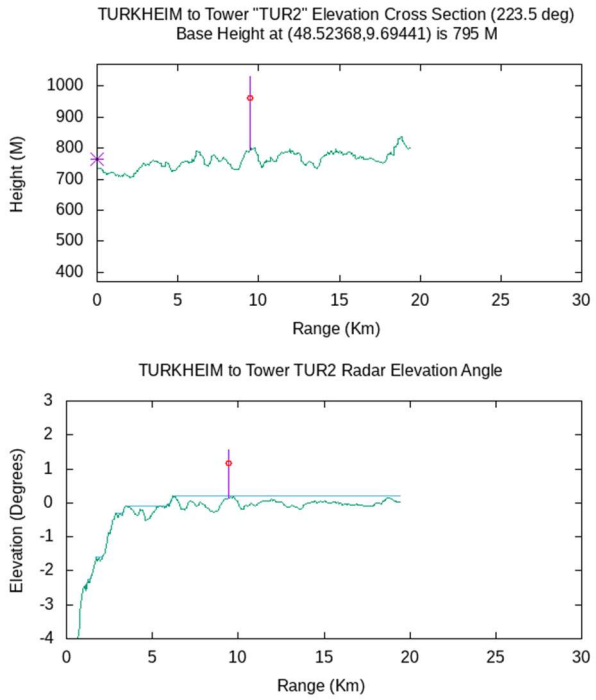
Line 330 “WT disturbance of DR”. I would say “on” rather than “of”. Not important.

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.

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)\



Coarse view of topography around TUR radar; SRTM30 data (~90m) as B-scan. Yellows are heights above 765m, which 735m ASL ground level at TUR radar plus assumed 30m antenna height. (Relates to Figure 3.)



Cross section from radar TUR to turbine “TUR2”. Top: topographic height ASL. Bottom: radar elevation angle of topography assuming 30m antenna height. In elevation image the flat lines extend from lowest elevation visible to next visible topography,