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Operational Wind Turbine Clutter Removal In The Finnish Weather Radar Network

Methodology and Impact on Data Quality

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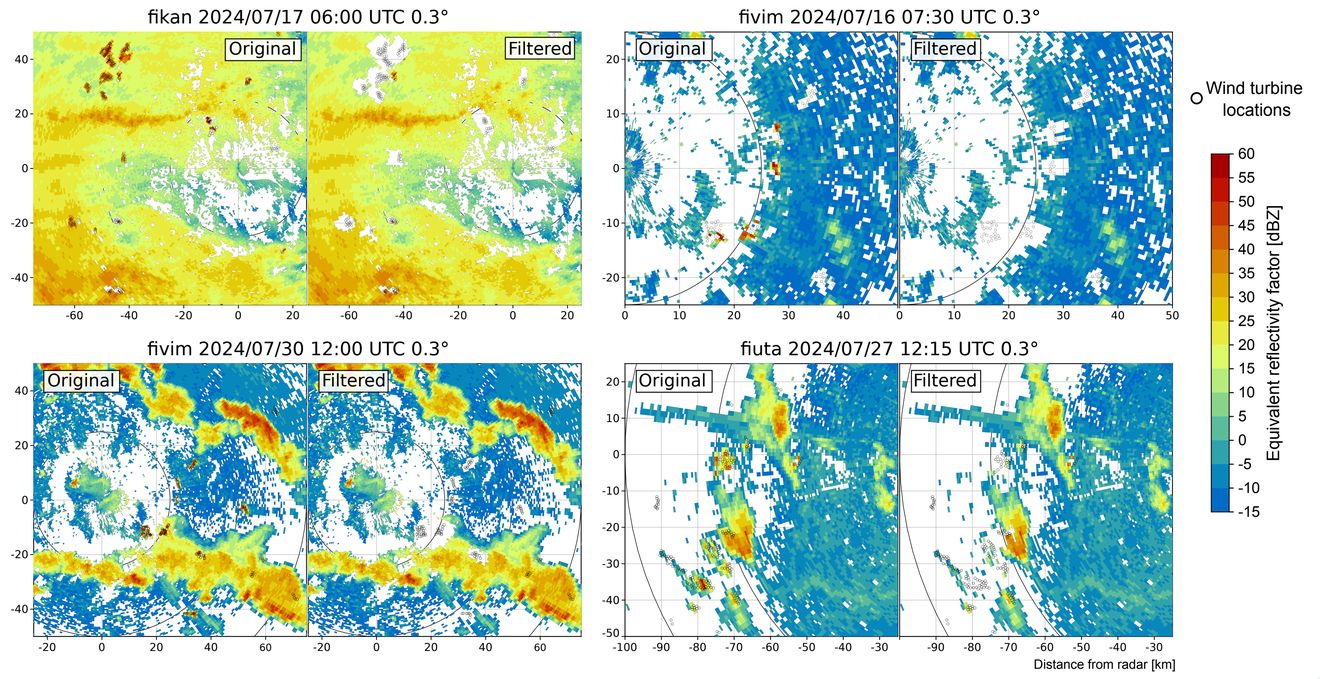
Wind turbine clutter removal algorithm

The algorithm (based on [1]) aims to remove strong wind turbine clutter areas that e.g. cause false alarms in radar-based CB[a] /TCU[b] detection. For now, the algorithm does not aim to remove the "clutter tails" with low radar reflectivity. The algorithm is applied as post-processing in polar coordinates separately to each PPI[c] scan only in areas surrounding known wind turbine sites.

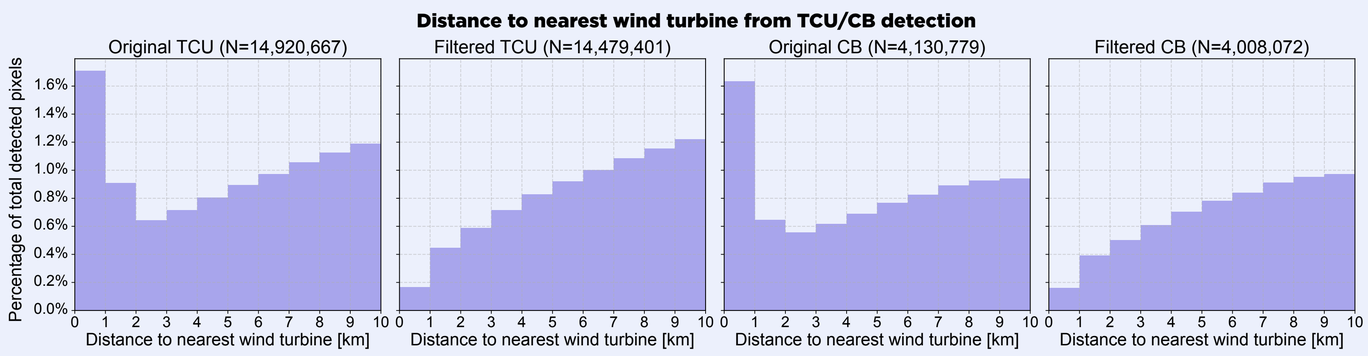
1. To filter strongest clutter, remove bins where
   - DBZH[d] > 20 dBZ
   - LOG[e] > 30 dB
   - PMI[f] < 0.5
2. To filter surrounding weaker clutter, in 10° x 10 radial bin windows around already-filtered bins, remove bins where
   - LOG[e] > 20 dB
   - PMI[f] < 0.65

Filtering examples

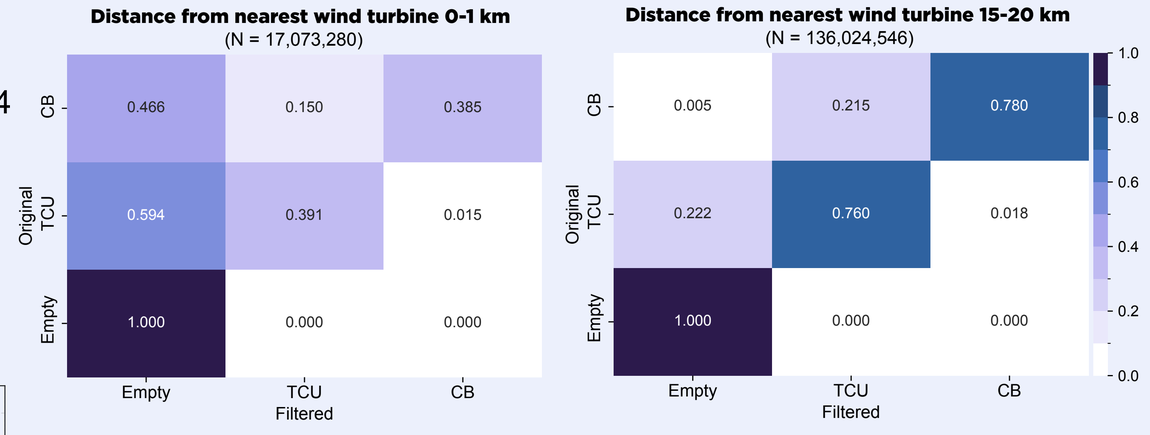


Impact of wind turbine clutter filtering on CB/TCU detection

- Original, non-filtered volumes compared to volumes with
  - wind turbine clutter filtering
  - rack-based removal of emitters, speckles and jamming [2]
  - rack-based gap-filling [2]
- Automatic CB/TCU detection algorithm [3] applied to 43 test days from 03/2023 - 01/2024
- To detect CB (TCU), 2 bins over 33 dBZ (15 dBZ) and 1 bin over 41 dBZ (32 dBZ) required in a vertical column without gaps

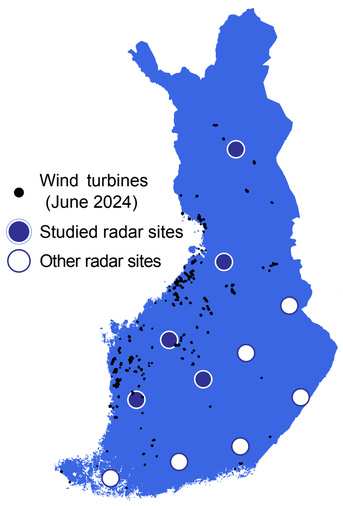


- In the distribution of CB and TCU pixels described as a function of distance from nearest wind turbine, the peak at distances of 0-2 kilometers is removed



- Close to wind turbine locations, 47% of CB and 60% of TCU pixels are removed by the wind turbine clutter filtering, and 15% of CB pixels are lowered to TCU class
- At distances of 15-20 km from nearest wind turbine, 0.5% of CB and 22% of TCU pixels are removed by other filtering performed with rack, with 22% of CB pixels lowered to TCU

Wind turbine clutter in Finnish radar network



- Data analyzed from 5 C-band radars (fivim, fiuta, fikan, filuo, fipet) for 2022-2023 (fikan from June 2022) from 0.3° PPI scans (0.1° for filuo) every 5 minutes
- Wind park area by drawing circles of 500 m radius around turbines
- Wind park clutter area from occurrence of radar reflectivies at thresholds of 8, 15 and 33 dBZ, with a dynamic occurrence threshold depending on range from radar

- At 8 dBZ threshold, clutter area is on average 2.3 times the physical area of the wind park
- At 33 dBZ threshold, clutter area is similar to physical area
- Ratio of clutter to physical area does not depend significantly on
  - range from radar
  - number density of wind turbines within the park
  - elevation difference between wind park location and radar beam (in normal progapation conditions), provided the main beam hits the park

- At ranges less than 100 km from radar site, most parks produce clutter at 33 dBZ and smaller thresholds
- At longer ranges, clutter is mostly present at thresholds ≤ 15 dBZ

Conclusions

- We present a simple, two-pass algorithm that is applied as post-processing at FMI
- The algorithm removes wind turbine clutter from the radar data effectively, resulting in a significant drop in false CB/TCU detections caused by wind turbines
- Wind turbine clutter is a major radar data quality issue in Finland and its impact is expected to increase in future
- On average, wind parks cause a clutter area of 2.3 times the physical park area at 8 dBZ threshold and 2.0 times at 15 dBZ threshold
- Future developments include improving the filtering of clutter at lower reflectivity thresholds and adapting the algorithm to filter "tails" caused by wind parks

References:

[1] Keränen, R., Alku, L. C., Pettazzi, A., and Salsón, S.: Weather Radar and Abundant Wind Farming – Impacts on Data Quality and Mitigation by Doppler Dual-Polarization, 8th European Conference on Radar in Meteorology and Hydrology, Garmisch-Partenkirchen, Germany, 2014.

[2] Peura, M.: Rack - a program for anomaly detection, product generation, and compositing, 7th European Conference on Radar in Meteorology and Hydrology, Toulouse, France, 2012. Software available at https://github.com/fmidev/rack

[3] Leroy, M.: Status of the Automatic Observation on Aerodrome and Ongoing Improvements in France, Proc. TECO-2006, WMO Tech. Conf. on Meteorological and Environmental Instruments and Methods of Observation, Geneva, Switzerland, 8, 2006.

Glossary:

[a]CB: Cumulonimbus
[b]TCU: Towering cumulus
[c]PPI: Plan Position Indicator
[d]DBZH: Horizontal clutter-corrected radar reflectivity
[e]LOG: Log receiver signal-to-noise ratio
[f]PMI: Polarimetric Meteo Index

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Algorithm development JR. Data analysis PA, JR & HH.
Visualization JR & PA. Conceptualization JR, HH, MK & AvL.

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