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Atmospheric Measurement Techniques
Discussions

# *Interactive comment on* "Airborne laser scan data: a valuable tool to infer partial beam-blockage in urban environment" *by* R. Cremonini et al.

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The authors wish to thank the anonymous reviewer for his valuable remarks.

One significant unstated restriction is that the theoretical blockage calculations are for a stationary antenna pointing in a fixed direction. Most weather radars are operated to collect azimuthal averages, combining 16 to 64 azimuthal samples over intervals of 0.5 to 1.0 degrees of azimuth. When considering blockage from real weather radar data this azimuthal averaging must be considered. This distinction is particularly important for vertical obstructions of intermediate extent, such as chimneys or towers (Hanasaari power plant), where the contribution to a larger azimuthal average will be less than to the worst single direction.

The authors agree with the reviewer. The Helsinki weather radars perform the low-



est PPIs at 15°/s antenna speed averaging 32 samples with 1000 Hz PRF. Hence, PBBs estimations have been revised considering the effective beamwidth according to Doviak and Zrnic (1984), Section 7.8.

Another unstated assumption is that the beam is uniformly filled with precipitation targets, especially in the vertical. The authors mention winter as a motivating consideration and in winter the assumption of uniformity in elevation is often broken. See Tabary (2007) "The New French Operational Radar Rainfall Product. Part I: Methodology" Section 3c in J. Weather and Forecasting.

The authors agree with the reviewer. However, the study focuses on obstacles located close to the weather radars (within few kilometres). To compare expected PBBs and QPE, the authors selected a case study characterized by stratiform precipitation with freezing level located around 1,900 m above sea level (see the radiosounding in Jokioinen on September 22th, 2014 at 12 UTC). Considering 1.0 degree elevation and 10-km range,under normal atmospheric propagation conditions the beam height is 132 m above the antenna centre with 96-meters beamwidth. Under these conditions the assumption of uniformly filled beam with stratiform rainfall is reasonable.

In terms of methodology, most of the equations given are ones one might find in any introductory text on weather radar. More detail needs to be given about the exact equations used for blockage estimation and how they are solved numerically. As mentioned in the paper, there already exist a few studies using Lidar DEM's, so how does the methodology here compare to them?

The beam propagation has been modelled dividing the beam in rays varying azimuth and elevation in the range of 3-dB width and applying the Equations (1), (2) and (3): the emitted power for each ray is given by $\varphi 0$ multiplied by P0 (the emitted power in the centre of the beam). When the obtained ray height is lower than ALS points, the ray is considered blocked. The total expected blocking is derived as the ratio between emitted power weighted unblocked and blocked rays.

The case of September 22, 2014 is shown and apparently used to estimate blockage from observations for comparison to the calculations, but there are only hints how this was done. One can guess that one or more plots of rainfall accumulation were plotted as a function of azimuth at one of more ranges. If so, show an example. What is the estimated accuracy of these estimates? For example if my understanding is correct, does one get similar numbers from different ranges? Also, as mentioned above, information about azimuthal averaging of the observed data is required for context.

The observed beam-blockages are estimated manually selecting rain profiles across the suspected azimuth and evaluating the unblocked rainfall QPE as average before and after the blockage. A plot showing a typical profile has been added. Finally error analysis of observed PBBs has been carried out. The simple average at different range can show different numbers due to ground clutter contamination.

I like the idea of getting an estimate of blockage uncertainty by adding some random errors to the antenna pointing axes. However the justification for the range of errors is not clear. What is meant when the article says "The antenna pointing accuracy for the three weather radar (sic) is about 0.1âŮę ". When considering where an antenna is pointing there are a number of considerations: How precise is the read back angle mechanism? Are the read back angles biased? How reproducible are the angles between scans (antenna control)? Antenna control in elevation is known to be an issue in some antenna systems and can have important implications for blockage, even if sun pointing show the hardware is good. In addition, the range of azimuthal averaging can depend on factors like temperature in the radome.

The authors agree with the reviewer: the overall antenna pointing accuracy depends on several factors; another strong assumption is the standard atmospheric propagation conditions. Nevertheless, 0.1 degree is the nominal antenna pointing accuracy required for operational weather radar.

Minor issues:



PPI maps showing calculated blockage might be nice, especially for comparison to Figure 5 (accumulation).

The map of PBBs for Kumpula weather radar at 0.5 degree has been added

How computationally expensive is all this? How would one use it operationally, or does one use it only for understanding? In the absence of good antenna control one might need to rely on read back angles (assuming these to be accurate) and multiple calculations, since angles might change from scan to scan.

The main source code is implemented by Python and the user time on Linux laptop with Intel(R) Core(TM) i7 CPU M 620 @ 2.67GHz is about one second per azimuth and elevation.

Any comment on the advantages of theoretical calculations from terrain height versus purely empirical estimation of blockage from radar echo statistics, as done on Sept 22?

The PBBs can be estimated purely from radar echo statistics. However, it requires long-time weather radar observations in stratiform rain. Theoretical estimations of PBBs provide benefits during the choose of the radar site for new installation or to define the best scan strategy (e.g. the choose of the optimal lowest elevation or definition of RHI scan directions).

Table 2 and 3 are inconsistent with each other and to a certain degree the text. Table 2 gives blockage as a range. Would it be better to give as an average (or median) "+/-" the standard deviations (or interquartile)? Table 3 omits estimation of variability.

Table 2 and 3 have been completely revised specifying the interquantile range. Consequently, Figure 8 - the scatter plot between observed and estimated PBBs has been updated.

Figure 8, the panorama, should be introduced earlier, in the discussion of Kumpala radar on page 3. Is it worth just extracting sections of the overall panorama for the individual features discussed in the text? For example, the subsection of the panorama with the Paavalin church that corresponds to Figure 3 is too small to see. The panorama is interesting, but is it all needed here? More detail about the panorama would be good. How were the panoramas created? Presumably the antenna is inside a radome. Images from a deck several metres below the antenna axis can be misleading when one considers objects that are relatively close to the radar. (4m height difference changes a target at 1km by 0.2 degrees) For example the impression of the Paavalin church at 190 degrees would probably be different.

The overall panorama has been introduced earlier in the text. The authors agree with the Reviewer about panorama uncertainties to determine exactly partial beam-blockage angles: the image was never intended for photogrammetic use in the paper. Here, the purpose is to provide to the reader overview of Kumpula's horizon.

It probably does not matter much, but it should be mentioned that obstacles less about 1km away from a weather radar may start to be in the near-field of the antenna, depending on the antenna size. If this is the case, geometrical optics start to be questionable.

We completely agree with the Reviewer. We added the sentence in the SubSection Methodology: "This method can not applied to obstacles located within antenna near-field region. For larger antenna the boundary between near-field and far-field region can be roughly calculated as R =2 D2 / $\lambda$ where D is the antenna diameter and $\lambda$ is the wavelength. Substituting antenna diameter and wavelength for Helsinki radars (D = 4.2 m and $\lambda$ = 0.0533 m), the far-field region starts at about 662 m far from the antenna."

Title has grammatical error: Should be either "Airborne laser scan data: a valuable tool to infer partial beam-blockage in an urban environment" or "Airborne laser scan data: a valuable tool to infer partial beam-blockage in urban environment environments"

We agree. Corrected.

Numerous grammatical errors seem to grow in number through the paper. At a minimum, careful vetting is needed for the title, abstract, intro and conclusion.



Revised.

"The 3" at line 14 on page 5 took a while for me to figure out.

Corrected.

The spelling "meters" is used for the unit of measurement. Contrast with "vapour". The article should consistently use American or International spelling of English. The journal can recommend which one.

We agree. Corrected.

The reference to Lang (2009) probably belongs in sentence about dual polarization.

We agree. Corrected.

The "Doppler snake" is a fanciful expression invented by Elena. Call it the zero-isodop.

We agree. Corrected.

This is disjointed: "<The> Figure 8 shows the 360âŮę panoramic view from the antenna tower of Kumpula radar: the main obstacles like Paavalin Kirkko bell tower, residential buildings in Itä-Pasila and YLE Studiotalo buildings with their television tower are clearly visible. The obstacle shapes have been gathered using a simple linear model; this approximation leads to underestimations or over-estimations in case of masts or complex shape buildings." I can only guess what the authors are trying to say. What are they referring to when they say "obstacle shapes have been gathered using a simple linear model"?

The panorama description has been clarified, specifying better main obstacles locations and directions. There was no attempt to reproduce 3D obstacle surface, providing a more realistic representation of obstacles. ALS data have been re-projected in radar-based coordinates (azimuth and elevation) and the mask is simply derived as staircase function. Example of these simple reproductions of buildings are shown in Figure 4 and 5 on the right, respectively the Pavillon Kirko and the Myyrmäki water tower.

As a remark, the application of LIDAR's extends well beyond urban environments. Blockage calculations for rural radars frequently fail because of forest canopy or individual trees within a few tens of kilometres of the site. Of course, in mid-latitudes blockage by deciduous trees can be seasonal, making ALS results different summer to winter.

We agree with the reviewer. The following sentence has been added in the discussion: "Blockage calculations for rural radars using ALS data have an additional limitation: in mid-latitudes the blockage by deciduous trees is seasonal, making ALS results different from summer to winter."

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