Anonymous Referee #1 Received and published: 4 January 2018

Review of: X-BANDDUAL-POLARIZEDRADARQUANTITATIVEPRECIPITATIONESTIMATE ANALYSES IN THE MIDWESTERN UNITED STATES Author(s): Micheal J. Simpson and Neil I. Fox Journal: Atmospheric Measurement Techniques (AMT) MS No.: amt-2017-439 General comments: This study presents a two-year evaluation of available X-band rainfall relationship performance for a Midwestern US location. The paper falls under the AMT scope as a validation manuscript. An objective is to analyze performance to extended ranges. Overall, the manuscript is not recommended for publication at this time. A resubmission (rather than revision) is recommended. Several points for the authors to consider. Extended comments:

1 ) Conclusions are counter to many published Xband studies. An author statement that initially caught my attention was, "This is surprising since ZDR has not been calibrated for the MZZU radar". While newer radars may have built-in controls to mitigate several issues, it is not typical. My experience is that radar quantities(Z,ZDR,KDP) out-of-the box are usually not suitable for hydrological applications (esp. over a two-year window). This is a dirty little secret of radar rainfall studies (all wavelengths), e.g., the processing effort to achieve their performance – increasingly problematic when others attempt to replicate performance. This is partially why manuscript "data/code availability" sections are of importance for journals such as AMT (is this now required?).

We appreciate this reviewer comment. We have revised this wording in our document to describe that although ZDR has not been calibrated, some of the errors may seem to offset over the long-term, revealing issues with long-term studies as opposed to short-term analyses. We are aware that it is ideal for, at least, S-band radars to fall within +/- 0.2 dB for accurate R(Z,ZDR) or R(ZDR,KDP) estimates. However, the system ZDR (ZDR offset) data, receiver/transmitter/sun biases were not available for analyses, but will be for future studies.

For a single X-band radar, handling data is nontrivial (attenuation corrections, influences from backscatter differential phase). This reviewer is skeptical, indications are that the authors opted for many tools/methods poorly matched to Xband. For example, superior performance for Z, ZDR-based estimators to longer distance (at X-band) – Z, ZDR can be highly problematic, less informative for 'real-world' rainfall estimation owing to detrimental attenuation corrections in rain, calibration uncertainties, complications in hail, nonuniform beam filling, etc. KDP-based algorithms are typically known for unbiased estimates and most accurate for cumulative (areal, total) studies. The study does not report hourly accumulation comparisons (most common way of visualizing rainfall performance), instead opting for many nonstandard comparisons. For 'false alarm' or detection-type concepts, it is unclear whether cross-correlation coefficient filters (or similar) are used to remove contaminants, other biological/insect echoes, etc. These concepts (thresholds) also change at X-band).

This manuscript indicates that "WDSSII" is used. This is an S-band reference – perhaps NOAA X-POL developments have provided modifications, but these are not obvious; older Ryzhkov technical reports are also S-band references, not X-band. Note, there has been recent effort put into Xband available to the authors – CSU Chandraseker, NSSL collaborations (Ryzhkov, Germany–use of specific attenuation based estimators), available open-source options. Z and ZDR offsets (e.g., modest 1 dBz or 0.1 dB type) alter performance 20%, moreso with larger coefficients associated with ZDR parameters – also may have other 'hot spot' or similar DSD-related influence modifications, etc., that impact shorter wavelength processing (e.g., Gu et al. 2011). It would be helpful for the authors to demonstrate that basic radar quantity estimates are proper, e.g., scatterplots, or dual-polarization self-consistency examples – as well as details on the typical attenuation corrections (radial examples?), associated coefficients and differential phase processing performed.

We thank the reviewer for these comments. To the best of the authors' knowledge, there is no direct algorithm in WDSSII that can specifically handle X-band data. However, the raw data and slightly QC'd data have been handled from the OU's mobile X-band weather radar and showed promising results in removing biological filters, ground clutter, and sun spikes. Regardless, this does not solve the issue of overall calibration previously mentioned, but is surprising the performance of particular algorithms for QPE.

2) Given the availability of extended gauge networks, others (including NSSL) have considered rainfall performances to longer distances. For Missouri, I would anticipate that other gauge networks (HADS type, e.g., https://hads.ncep.noaa.gov/) are also available. It would seem that this topic (performance to longer ranges) is still a useful, but needs better support. For an effort that does not introduce a new approach, there is an underwhelming number of gauges / comparisons (as compared to studies that benefit from mesonet gauges, iFloods, etc.). Besides, X-band 'gap filling' idea / motivation is usually not suggestive that X-bands would provide estimates to longer distances, but fill-in and outperform S-band radars in 'gaps' in coverage (lower-levels, etc.). Xband radars are typically not expected to provide rainfall beyond 40 km.

One of the surprising findings from the study is that the performance of the algorithms did not degrade as quickly as one would think; NSE's in the region of 100% beyond 40 km were still possible for specific algorithms in spite of the lack of calibration, leading to a further justification for using X-band radars for 'gap-filling' purposes.

Although HADS, CoCoRaHS, GHCN, USHCN, etc. have gauges for Missouri, they tend to be sparsely available for the center of the state. We have gathered data from many of these networks and will provide a more in-depth analyses of fewer algorithms with more gauges to prove the robust capabilities of the algorithms implemented. However, for many regions (particularly to the West), gauges are lacking to validate QPE, which was demonstrated for this paper.

3) Red flag: S-band algorithms. Missouri should be climatologically comparable to Oklahoma, Iowa, Colorado, which have many Xband studies to draw from. There is never justification for S-band algorithms at X-band (e.g., KDP is substantially larger, e.g., 3 times, at X-band than at S-band, etc., and Z, ZDR having different and unique shorter-wavelength nonRayleigh implications, etc.). One would also expect vastly different 'matched' R(Z), R(KDP) relation coefficients (e.g., as from disdrometer, etc).

The inclusion of the S-band algorithms proved that the KDP-containing algorithms did, indeed, provide vastly larger QPE's, yet for algorithms containing only Z or ZDR, they performed very well. Assuming standard Rayleigh-scattering, the Z-containing algorithms should, theoretically, not be effected as much as the KDP algorithms, which was demonstrated in this paper.

4) Confusion may also be attributed to selection of metrics (multi-year cumulative comparisons can appear correct for incorrect reasons). Providing performance contingent on rainfall rate intensity or hourly comparisons is preferable for many reasons, e.g., if the parts to the dataset primarily contributing were 'light' rainfall (R < 5 mm/hr, or hourly accumulation < __ mm, etc.), it may be more

acceptable/believable that R(Z, ZDR) was outperforming other methods than in the presence of heavier rainfall, etc. For example, it may be fair to expect R(Z,ZDR) should perform better in light rain to closer (or lengthier) distances, provided there was not much precipitation along that path (aka, attenuation in rain to that location). Many dual-polarization methods tend to work optimally in heavier rainfall, etc.

Thank you for this comment. The inclusion of statistical analyses with respect to rain rate would be a very good idea. This would decipher which algorithm performs better in different seasons and whether stratiform/convective events were more prevalent. Currently, a radome-wetting algorithm is underway to mitigate the effects of heavy rainfall directly over the radar (due to a complete loss in signal).