Atmospheric Measurement Techniques Discussions

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Reply on RC2

Guy Delrieu et al.

Author comment on "Sensitivity analysis of attenuation in convective rainfall at X-band frequency using the mountain reference technique" by Guy Delrieu et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-8-AC2, 2022

Reviewer 2: In this study, the authors address the impact of attenuation in rain on the radial profiles of radar reflectivity at X band. Five different equations parameterized by the radar miscalibration error dC, radome attenuation PIA_0, the error in the path-integrated attenuation PIA_m estimated from the mountain radar signal, and the multipliers a_{AZ} and a_{AK} in the power-law A – Z and A – K_{DP} relations are used to retrieve the unbiased radial profile of Z. Four of these equations are nonpolarimetric and three of them are constrained by PIA_m whereas the fourth is a classic Hitschfeld-Bordan solution which is very unstable for higher values of PIA_m. The four unknown parameters are varied in different combinations within certain ranges and the combination which yields the best match between 5 radial profiles of retrieved Z is considered a solution for all four parameters. The authors found that the estimated values of a_{AZ} and a_{AK} using their approach are consistent with the corresponding values derived from the simulations based on the DSD measurements and claimed this as a feasibility test of the method.

Comment/reply: Thank you for the time / effort spent on reviewing this article and the good summary made above.

Reviewer 2: It is difficult to read this manuscript. There are too many parameters and equations.

Comment/reply: We can understand this comment! We may consider presenting much of section 2 as appendices in the revised version (although this is not recommended in the AMT authors' guide). On the other side, we found important for the “young generation” to revisit in some detail the attenuation problem which is known to be severe at X-band and higher frequencies, and not negligible at lower frequencies (e.g at C-band). The mathematical formalism exposed is inspired by the seminal article of Marzoug and Amayenc (1994), two scientists I had the pleasure of interacting with some decades ago.

Reviewer 2: For example, I had hard time to realize that PIA_0 and PIA_m are identical to $AF(r_0)$ and $AF(r_m)$ expressed in a logarithmic scale.

Comment/Reply: This was explained in lines 135-141.

Reviewer 2: Equation (3.1) for the cost function is not understandable and requires more explanation. I guess that most of the readers (including myself) may not be familiar with the LHS technique and the Nash-Sutcliffe Efficiency (NSE) measure of the difference between two radial profiles of Z. These have to be defined and explained in a more detail as well as the terms OPS and NOPS.

Comment/Reply: OK, we will try to improve these points in revising section 3.1 which exposes actually the core of the methodology. Readers may be a little tired by the time they reach this point, all the more reason to try to lighten previous section 2 with appendices. The cost function is a simple mean of NSE coefficients calculated between pairs of reflectivity profiles corrected with the AZ algorithms (first 4 terms) and between pairs of PIA profiles involving the polarimetric algorithm (last two terms). The NSE is an interesting metrics (a kind of correlation coefficient) since it is sensitive to the correlation but also to the bias between the compared data. The LHS technique is quite popular in computer experiments as a sampling method of multidimensional spaces of parameters. We used the lhs R package for its implementation. Finally, OPS stands for 'optimal parameter set", i.e. a set of parameters leading to a cost function value greater than a given satisfactory threshold, in other words a parameter set leading to a good convergence of the considered reflectivity and PIA profiles. NOPS stands for the "number of optimal parameter sets" obtained for a given simulation, e.g. for a particular event, for given values of the calibration error and the exponents of the A-Z and A-Kdp relationships, for given ranges of variation of the LHS sampled parameters, etc. The NOPS is used for instance as a metrics to determine values of the calibration errors (Fig. 7) or to evidence the slight non-linearity of the A-Kdp relationship (Fig. 8).

Reviewer 2: It is not clear what is the ultimate purpose of the effort – more accurate QPE in the mountainous areas? Is there intention to estimate rain rate from corrected radial profiles of Z? It is well known that Z-based rainfall algorithms are not optimal and the methodologies based on K_{DP} and Ademonstrate much better performance, particularly at X band. It looks like using ZPHI-like retrievals of the radial profile of specific attenuation A and the R(A) relations is a more efficient and economic way to quantify rainfall. Moreover, the authors have benefit of determining the variable parameter $\alpha = A/K_{DP}$ because they can directly measure the path-integrated attenuation PIA_m using radar echoes form the mountains in their area along with a total span of differential phase $\Delta\Phi_{DP}$ over the propagation path.

Comment/reply: Thank you for these very interesting comments. Regarding the ultimate purpose (ambition!?) of the work, I would say that this article represents one step in the construction of an observational model dedicated to the estimation of atmospheric precipitation in all its forms (liquid, but also melting and solid) in a high mountain context with the rich observations collected within the RadAlp project. The idea is to formulate all available equations from all sources of information (backscattered power, polarimetry, … mountain returns!) in a rigorous mathematical framework and to consider the problem of parameter optimisation through a generalised sensitivity analysis (GSA) approach. By GSA, we mean considering the simultaneous effect of variations in all the parameters together and not the isolated effect of the variations of one particular parameter (e.g. the influence of the prefactor of the A-Kdp relationship on QPE). As proposed in this article for the "simple" case of convective precipitation with no ML contamination, this requires defining the structure of the parameters (inter-dependencies, *a priori* values, physical ranges of variation), exploring the parameter space with *ad hoc* sampling techniques, defining "cost functions" and "satisfaction thresholds" and performing the analysis of the statistical distributions of the *a posteriori* parameters. We have obtained encouraging results regarding the possibility to estimate calibration errors, radome attenuations, parameters of the A-Z and A-Kdp relationships (consistent with those derived independently from ground-based DSD measurements) using radar data alone. As noted at the end of the conclusion: "As a next step, we plan to extend the procedure to stratiform events with MOUC radar measurements made at times within or above the melting layer (added comment: i.e. in snow or melting precipitation; How can we estimate the coefficients of the A-Z-Kdp-R relationships for snow and melting precip?). The multi-angle, multi-frequency, polarimetric measurements of the valley-based radars will be critical in this respect for the characterization of the ML from below (Khanal et al. 2019, 2022) and the mitigation of the mathematical ambiguity of the physical model of interest". We may add that such a procedure is likely to be difficult to implement in an operational context due to its principles and computational costs. It may find its utility for the parameterization of radar QPE algorithms as well as for post-event analyses.