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Reply on RC3

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-AC3, 2022

Reviewer 3: This manuscript describes a combined QPE algorithm based on polarimetric X-band radar measurements as applied in the mountainous terrain. I suggest that the authors revise the manuscript having in mind comments below.

Comments/reply: thank you for the time spent on this review and for the valuable comments made

Comments

- It would be beneficial for this paper if you can provide some quantitative information on how the results of your algorithm developments and attenuation estimates would benefit the accuracy of QPE retrievals compared to existing algorithms.

Reply:

As explained in our reply to reviewer 2's last comment, "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".

In other words, rather than a "combined QPE algorithm", we are proposing a procedure for optimising the parameters of the equations describing the attenuation physics, the results of which could be used in an operational QPE system.

Since the article is already rather complex and lengthy, we have made the choice in the first version to focus on the estimation of the coefficients A-Z and A-Kdp relationships, the calibration error and the radome attenuation by using the MRT PIA measurements, and to leave aside the following problem of rainrate estimation.

Within the final stages of his PhD, Anil Kumar Khanal is being performing an assessment of various QPE algorithms using the parameterizations obtained in this article with respect to independent raingauge data. Including such forthcoming results in the revised version of the article may be an option we have to consider.

- Would a simple R-Kdp based QPE method still have important advantages? This method is insensitive to attenuation and to the radar absolute calibration errors and may be preferential for moderate and heavier rainfall.

Reply:

The R-Kdp method is one of the good candidates for QPE. In our context, its parameterization for liquid precipitation could be based on the available DSD measurements. The ZPHI method (Testud et al. 2000) has also very interesting properties (independence on dC, akz, on-site attenuation). Being a "rain-profiling algorithm" using both reflectivity and phidp profiles, we have a preference for the latter polarimetric method due to the noisiness of the phidp measurements for low to moderate rainfall. However, one more time, comparing QPE algorithms is not our goal in this article: we are using attenuated reflectivity profiles, Phidp profiles and mountain-derived PIA estimates to optimise (some of) the parameters of the attenuation equations.

Optimizing the R-Kdp and R-A parameters would require including the additional raingauge measurements in the GSA framework. This is certainly desirable but not implemented in the current version.

- Mountain references are available only for a fraction of the radar beams. Please be more specific about how these limitations influence you approach.

Reply:

We are not "promoting" MRT-constrained A-Z algorithms over polarimetric algorithms. We just want to outline that there is some valuable information in the mountain returns. Similarly, in satellite configurations, we could claim that the Surface Reference Technique brings additional information wrt dual-frequency measurements of the GPM core platform.

However, in some vulnerable valleys in high-mountain regions, one could well get "belts" of mountain targets allowing implementation of MRT-constrained A-Z algorithms in a continuous manner in the inner domain.

For convenience, our down-valley based X-band radar (XPORT) has been set up on the roof of the laboratory, but we have in mind a number of locations where it could be installed for an effective precipitation monitoring over the entire city of Grenoble with the MRT approach.

- Does mountain reflectivity depend on the wetness of the ground targets? If yes, then "dry environment" reference measurements are not exactly applicable to rainy conditions.

Reply :

This problem has been addressed in several previous publications of our team, the most informative being probably https://doi.org/10.1175/1520-0426(1999)016<0405:RMIHTW>2.0.CO;2, 1999 and more recently https://doi.org/10.5194/amt-13-3731-2020, 2020.

As explained in the article, (i) selecting strong mountain returns (typically greater than

45-50 dBZ) allows to mitigate the impact of precipitation falling over the target (negative bias), (ii) a refined estimation of the so-called dry-weather baseline is required to account for the possible modification of backscattering properties of the mountain surfaces before and after the event and (iii) the time variability of the dry-weather returns defines the minimum detectable PIA.

- What is natural variability of the coefficients in A-Z and A-Kdp relations (eg, due the rain type – convective vs stratiform)?

Reply:

Some information is available in the article on this subject from the DSD-derived relationships presented in Figs 5 and 6 with comments made in the text (lines 460-485). We actually used the DSD-derived scatterplots between the variables of interest for all the types of precipitation observed in the Grenoble area to define the central values and the ranges of variation of the exponents and prefactors in the GSA procedure.

We have to add that in the assessment of the QPE algorithms wrt raingauge data that is being performed, we found necessary to consider an R-A relationship fitted on convective precipitation rather the one fitted over all precipitation types, due to a missfit of the highest rainrates in the latter.

- There has been a significant number of studies deriving X-band A-Kdp relations using different approaches including model calculations and also the direct use of observational data (e.g., Bringi and Chandrasekar 2001 book, https://doi.org/10.1175/JTECH1763.1 https://doi.org/10.1175/JTECH1804.1 https://doi.org/10.1175/JTECH-D-13-00231.1 to name a few). It would be appropriate to compare (at least briefly) your relations with previous ones and also to provide a measure of uncertainty in the coefficients of these relations.

Reply: Yes! We recognize that such references and comments are missing. We will include them in the revised version.

- Line 591: I believe it is "backscatter phase shift" not "phase shift on propagation". Also, non-uniform beam filling affects other approaches not only a polarimetric one.

Reply: yes for the first point, thanks. Yes also for the second one!

- Fig.2: There is a wedge of the high Phidp increase indicating heavier rainfall (17:00 UTC). However, (unlike for the Phidp wedge at 16:05 UTC) there is no corresponding high reflectivity areas (even in the closest to the radar range gates within the high intensity cell, where total attenuation is expected to be not yet significant). Please explain. Also, adding SNR frames can help to better interpret Fig. 2 data.

Reply: This is due to 2 factors: first, the big radome attenuation evaluated to about 10-15 dB and secondly the displayed reflectivity range which is limited to 10-60 dBZ. A complementary display can be found with the 2 examples of profiles in Fig. 9 within and outside the wedge. We will extend the display reflectivity range to [-10, 60 dBZ]

- It appears that there are pixels (and clusters of pixels) of high rhohv values (at 14:00 UTC), which are not associated neither with rain cells in the Zm graph nor with the mountain slope echos. Please explain.

Reply: Light rain? Again, this may be related to the effect of the 10 dBZ lower limit for the displayed reflectivity.

- Figs. 1 and 2: Please, increase the font size of numbers in the graph axes and color bars (currently the numbers are impossible to read) and show units on the color bar (e.g., dBZ in Fig. 1, right frame).

Reply: This will be done.