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Interactive comment on "Retrieval of snowflake microphysical properties from multi-frequency radar observations" *by* Jussi Leinonen et al.

Anonymous Referee #2

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Several studies have investigated how snow properties affect multi-frequency radar measurements. For example, it has been shown that triple-frequency observations are sensitive to particle effective density. This manuscript takes the logical next step, to make use of the found relationships to retrieve snow properties from observations.

To introduce a new retrieval concept the manuscript is surprisingly complete. For example, it describes the methodology well, reports errors, explores the sensitivity to a priori assumptions, and provides a careful analysis of application on field data. Some nice technical solutions are also presented, such as basing the forward model on tabulated data and determining the posterior expectation value by actually integrating the Bayes' equation. The manuscript is also well written.

My criticism will be limited to a single issue, an assumption that I strongly think needs to

be investigated. The assumption is that β is set to have constant value ($\beta = 2.1$). If the study would had been limited to non-rimed snow I would have accepted the assumption, but identification of graupel is discussed in at least Sec 5. In the Conclusions section the detection of both graupel and hail is discussed. As far as I understand, graupel and hail are generally considered to have β well above 2.1. For example, Locatelli and Hobbs (JGR, 1974) found graupel type particles to have β between 2.6 and 3. Heysmfield and Kajikawa (JAS; 1987) reported values between 2.38 and 3.21. In addition, not any value of α can be combined with a given β, as will be discussed blow.

In summary, I think $\beta = 2.1$ is not realistic compared to the scope of the retrievals. Presumably, the authors decided to set β to be constant to obtain a state vector (x) having three elements, to match the length of the measurement vector (y). Here I want to point out that in a Bayesian framework there is no fundamental problem to let x have more elements than y, and there should not be a problem to incorporate β in x.

The main obstacle is to derive the additional a priori data required. If the measurements at hand do not allow this, I suggest to make some educated guesses. I would assume a high correlation between α and β, as a reasonable combination of α and β must roughly correspond to solid ice particles for sizes down around 50 μm. That is, the mass predicted at 50 μm should not deviate hugely from the mass of a solid ice sphere having this diameter. To illustrate this physical link between α and β, I attach a figure based on the combinations of α and β found in Table 1 of Kulie et al. (JAS, 2010). The data (blue markers) don't represent snowflakes or graupel, but should still clarify that α and β are highly correlated due to basic considerations (or rather that the unit of α changes with β). The authors already assume significant correlation between elements in x (Eq. 17), so assuming this for α and β would not introduce something fundamentally new.

For comparison, the red marker in the figure indicates the a priori value applied by the authors. The red line shows the $\pm 2\sigma$ a priori range assumed (including the factor of 1.5). That is, the red line represents the range of α and β values spanned by the a priori assumptions applied, which seems to be a quite narrow range compared to the possible range.

In any case, I think the assumption of a constant β requires much more attention than the few comments given on page 6 (lines 10-13). At least some sensitivity analysis is required, but I would suggest to actually try to include a fit of β in the retrieval. This could potentially improve the retrieval performance even further.

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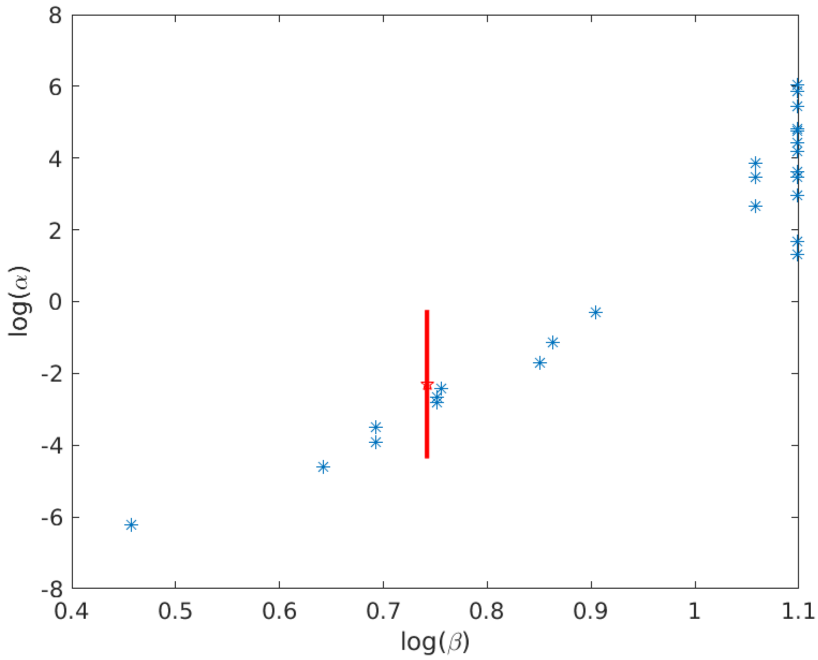

Fig. 1.