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Interactive comment on "Introducing hydrometeor orientation into all-sky microwave/sub-millimeter assimilation" *by* Vasileios Barlakas et al.

Anonymous Referee #1

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Overview The manuscript "Introducing hydrometeor orientation into all-sky microwave/sub-millimeter assimilation" describes an approach to improve agreement between simulated and observed polarized microwave brightness temperatures in the assimilation of cloudy remote sensing data. In lieu of implementing a fully-polarized radiative transfer model into the data assimilation scheme, the authors propose to adjust the extinction of "unpolarized" cloud and precipitation scattering properties with an extinction ratio. Such a characterization has sufficient rooting in the body of literature, and it is based on the knowledge that first order scattering effects are the primary mechanism by which clouds and precipitation modify propagating electromagnetic waves. While the overarching approach is well-grounded, there are significant gaps that need to be addressed. Significant information needed to assess

the manuscript is missing. The implementation itself is presented more as a fitting exercise with very loose connections to cloud and precipitation physics and the related radiative transfer. The parameterization of the extinction ratio is a bit simplistic, and its application is overgeneralized.

Specific comments Lines 92-98: The "microphysical setup" that is used for the RTTOV forward operator is based on manuscript that is in preparation (Geer 2020), and not available to consider for the review. Salient details are missing, and those details are necessary to properly review this manuscript. Some of this information is basic: What are the size ranges for the different ice habits? But, there are deeper details that need to be considered. The use of a model like Liu's sector snowflake to cover a broad range of ice types makes sense. However, expanding the ice microphysics to multiple ice habits, each with associated high-fidelity scattering properties, offers an opportunity implement a microphysical approach that has a physical basis. While these ice models may be the best numerical matches, the morphologies of the habits selected don't intuitively map to the stated ice classes, with the exception of cloud ice, and there is very little insight into the selection processes.

Table 1: The reference for the sector snowflake should be Liu 2008. Also, following the previous comment, please add the size ranges for each liquid and ice habit.

Lines 154-155: The process by which hydrometeors align, and how size relates to alignment needs to be considered in significantly more detail here.

Line 159-161: The salient details of [Brath et al., 2020] that are applicable to this manuscript, i.e., a description of the geometry including particle and laboratory reference frames, need to be included. There needs to be enough information to make this paper understandable on its own. As part of this, "tilt" needs to be defined.

Line 203: One month of data doesn't seem sufficient to represent the full range of brightness temperatures and polarization differences.

Line 235: Based solely on Figure 2, why not 1.2? This is certainly within the distribution of the observations, and follows the trend of the observations. especially for combinations of low Tbv and low PD.

Line 259: The higher ratio for 89 GHz compared to 166 GHz doesn't make physical sense, given that polarization differences at 166 GHz are noticeably higher (and the plot in the appendix suggests that the agreement degrades with increased ice scattering).

Figure 4: Looking at this plot, the distribution seems a bit bifurcated (but this *could* be an artifact of insufficient data, referencing previous comment for line 203): one high-slope relationship that contains a large bulk of the data, and another that exhibits significantly more downward curvature with increasing ice scattering. It's also the curve with the lowest Tbv values. The analysis presented in this paper seems to be fitting to the high slope data. It would be instructive to also plot something like 5b here.

Figure 5: This plot doesn't offer much since this is really a bi-variate distribution, or even better, it should be paired with the mono-variate histograms of Tbv.

Section 3.4: Overall, this section is a bit confusing, and it doesn't add much in it's current form. Referring to the radiometer bands as numbers (instead of frequency and polarization) definitely make it more opaque. Also, why ATMS? The consideration of polarization is significantly more complicated than the conical scanner, and the polarization ratio has not been characterized over a range of incidence angles which means that the method developed in this paper is not applicable to most of the data.

Line 334: reducing extinction, not scattering

Lines 340 and 341: again extinction, not scattering

Section 4.1, first paragraph: The description of why the polarization differences approach zero again for deep convection is incomplete. Yes, multiple scattering depolarizes the radiation; however, particle morphologies and orientations within a dynamic environment are also at play: spherical (or less oblate) hail and graupel that may be

tumbling in the turbulent environments in which they form, although these processes are not well understood [Jung et al 2009].

References Jung, Y., Zhang, G., & Xue, M. (2008). Assimilation of Simulated Polarimetric Radar Data for a Convective Storm Using the Ensemble Kalman Filter. Part I: Observation Operators for Reflectivity and Polarimetric Variables, Monthly Weather Review, 136(6), 2228-2245.

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