Final Author comments:

Review 2

Comment 1:
The authors mention that 45 degree elevation angles are often optimal for polarimetric measurements. How about for Doppler spectral measurements? It would seem to me that off vertical measurements, for which horizontal advection of hydrometeors might contribute to the information content of the Doppler spectra, is more problematic than for vertically pointing measurements. Might this be the case? My opinion is that addressing this issue in the paper, albeit even briefly, would be of value. Are Doppler spectral and polarimetric measurements optimized at the same or different elevation angles?

Answer:
The radial velocity can be seen as a combination of the radial wind speed coupled with the intrinsic cloud particle fall velocity. The particle fall velocities contain a wealth of information regarding the particle size distribution. The more off vertical the measurement is performed, the more the Doppler spectrum is affected by the horizontal wind component which often has a higher order of magnitude than the vertical wind velocity and particle fall velocity combined. The fall velocity information is therefore optimally retrieved when performing vertically pointing measurements, the horizontal wind component being orthogonal to the radar line of sight and therefore considered negligible.
Conversely, polarization diversity measurements (polarimetric measurements) which benefit from the non-spherical shape of falling oriented hydrometeors are most effective when performed close to the horizontal plane.
Doppler and polarimetric measurements are therefore not optimal at the same elevation angle. However, as mentioned in page 532, line 15, a trade-off at 45 degrees elevation is actually taken to optimize the combination of both. Although, it is worth noting that the fall velocity spectrum retrieval requires several processing steps which are considered beyond the scope of this paper.

This will be clarified in Section 2.1 as well as in the introduction when the use of radial Doppler velocity measurement is explained (Page 529, line 29).

Comment 2:
As I see it, at the heart of this paper is establishment in an illustrative way only the connection between the three spectral polarimetric parameters and ice crystal types and orientations. As such, these connections have to be made as clear as possible in the paper. The two places in the paper where this is currently done are Figures 2 and 8 with their associated text. And I struggled to understand the details of these two figures and their associated text.

Consider Figure 2 first. This looks to me to be a cartoon schematic with important details left out. For example, what attribute of the ice crystals in the schematic gives them different velocities? I could not find this information on Page 533 or in the caption for Figure 2. In the schematic it looks like the orientation of a prolate spheroid is doing it: when the prolate spheroid symmetry axis is vertical the velocity is low and sZdr is low; when the prolate spheroid symmetry axis is horizontal the velocity is high as is sZdr. Is this what the curve for sZdr is meant to connote? Is having the circle just left of the zero meant to indicate that sZvv, sZhh and sZdr are zero for all velocities? This is never stated. Finally, I have no idea what particle sizes and shapes are associated with sZvv and sZhh. Is "Velocity" radial velocity or fall velocity? What elevation angle is intrinsic to this figure? This is never addressed. Figure 2 is an important figure and I know that I am not taking from it what I ought to in its current form.

Answer:

I thank the reviewer for pointing out the weaknesses of Figure 2. Every spectral polarimetric parameter is defined in terms of the radial Doppler velocity measured from the radar. The radial velocity can be seen as a combination of the radial wind speed coupled with the intrinsic cloud particle fall velocity. On the one hand, the radial wind depends on the dynamic of the atmosphere and the radar elevation. On the other hand, the fall velocity spectrum is related to the microphysical properties of the ice crystals , i.e. particle size distribution, density, and particle Area projected normal to the vertical airflow (Mitchell, 1995). Any changes in the radial wind and/or fall velocity affect the radial velocity and therefore the spectral polarimetric output.

The retrieval of ice crystal attributes, and especially the particle size distribution of each particle type, from radial Doppler velocity is rather complex. As the paper is focus on spectral polarimetric parameter processing, the microphysical interpretation of Figure 2 in terms of particle size and concentration is considered beyond the scope of this paper. However, compared to other spectral polarimetric parameters, sZdr can provide quite straightforward information on particle orientation dominating the signal for a specific Doppler interval (positive when horizontally aligned particles dominate the signal, negative when vertically aligned and close to zero when particles do not exhibit any specific orientation). sZdr is therefore chosen in this paper to introduce the potentiality of spectral polarimetry for microphysical retrieval purposes as well as to categorize the microphysical diversity within the probed medium as used in the application section (Section 3).

An improved version of the introduction of Section 2.2 will be provided in the new version of the paper.

Perhaps a better Figure 2 would start with explicit size distributions of some sort for appropriately shaped spheroids. Then, explicit calculations of sZvv, sZhh and sZdr for these distributions could be made for an explicit TARA viewing geometry. Such an exercise ought to lead to a Figure 2 with lots of information and no ambiguity if the process used to generate it is clearly described in the text and caption. Whatever you choose to do for Figure 2, the information content associated with it needs to be improved.

Answer:

Figure 2 will provide an example of polarimetric spectra (sZdr and sZhh) obtained from an explicit distribution and viewing geometry as advised by the reviewer. The associated text will clearly describe how such a distribution impact the spectra and how sZdr can be used for particle categorization retrieval.

I have many of the same comments for Figure 8. Again, these look to me to be schematic diagrams with important details left out. For example, you must have in mind the idea that different mixtures of what look to be oblate spheroids, prolate spheroids and spheres lead to different trends of sZdr with velocity. But it is not clear to me what aspects of particle type concentrations, particle type sizes and particle type orientations lead to the different sZdr spectra that you show. You provide two sentences of description for Figure 8 on Page 540 but these are not enough for me to understand in any detail what is going on in Figure 8. Figure 8 is a challenge. It is full of important information for this paper and how can one make clear the microphysical underpinnings of each of the 16 categories in a succinct way?

Answer:

As explained previously, sZdr alone is not capable of providing any direct information on particle concentrations and sizes. A full microphysical description can only be achieved by the simultaneous use of other spectral polarimetric parameter more sensitive to such particle attributes. However, sZdr spectra provide the possibility to categorize the particle types present in the radar resolution being probed depending on similarities in terms of particle orientation and particle motion. A categorization based on these two attributes is therefore considered in Section 3. The clear microphysical underpinnings asked by the reviewer is only achieved after further processing steps, where other spectral polarimetric parameter information are taken into consideration.

For future work, an improved categorization procedure should be created based on the synergetic use of all spectral polarimetric information (and most probably complemented with a microphysical cloud model aimed at inferring particle size distribution for each particle types found in the radar resolution volume).

Comment 3:

"unwanted echoes" are mentioned in the last sentence of Sec. 2.2.2. After reading this sentence I did not know what to look for in Fig. 3b. Show me the unwanted echoes in Fig. 3a and where they go in Fig. 3b and then I think I will understand what you mean here.

Answer:

The unwanted echoes (clutter) are defined as echoes which are not satisfying the polarimetric signature expected from meteorological targets.

The unwanted echoes will be shown in Fig 3b in a different color in order to distinguish them from the signal kept after double sL_{DR} clipping is being applied.

Comment 4:

In the last sentence of Sec. 2.2.3 the phrase "the velocity window" was used. But I had yet to see any definition of this "velocity window" so was not sure what was meant by it.

As I later worked through Figure 4 I figured out that by “velocity window” the authors meant the region of spectral data that survived all of the tests. I think showing explicitly the thresholds and regions of data that survive them would make the idea of these windows clear in Figures 3 and 4. I have added dashed lines on Figure 4 to illustrate one possible way of doing this.

Answer:

‘Velocity window’ shall be replaced by ‘velocity interval’ for clarity sake. Figures 3 and 4 will also be re-arranged. The Doppler range will be reduced to Doppler intervals where data are present, and thresholds will be added in Figure 4 to better illustrate the type of clipping performed.

Comment 5:

What does “on consecutive Doppler bins” mean at the bottom of Page 535? Is this consecutive in velocity at one time or consecutive in time at one velocity? I need to be sure that I understand clearly what is meant by Delta sRHOco.

Answer:

‘On consecutive Doppler bins’ means consecutive in velocity at one specific time.

Comment 6:

I am not sure what is meant by “gradient” in Fig. 6 because it looks to me like the gradient of “std” in Fig. 6b is most always negative but with positive slope from the 12th to 13th spectra averaged. Yet the gradient is always positive in Fig. 6 and never changes sign. I found this confusing. The same is true of Fig. 6c.

Answer:

The reviewer is indeed right to point out this mistake. Because only the magnitude of the gradient is of interest in this paper, the absolute value of the gradient was taken for both figures rather than using the value of the gradient itself.

This will be corrected in the figure.

Comment 7:

The explanation of Eq. (8) needs a bit of work. See my comments on Page 542. I hope that these comments are at least legible.

Answer:

Eq. 8 is based on the $s\rho_{co}$ values that can be found within a single Doppler spectrum. It is considered in this retrieval that Doppler bins where $s\rho_{co} > 0.995$ are only related to presence of aggregates. Conversely, several simulations show that pristine ice particles are dominating when $0.95 < s\rho_{co} < 0.97$. Looking at the ratio obtained from the $s\rho_{co}$ histogram for these two $s\rho_{co}$ intervals, it is possible to infer the aggregation level of the radar volume, a large number representing strong aggregation regions.

It is worth to notice that this ratio is also in an experimental phase and is only meant to demonstrate the potentiality of spectral polarimetry for microphysical retrievals.

This comment will be taken into account in Section 3.3.

Comment 8:

I think using discrete and more distinct colors for Figs. 10b and 10e would greatly improve the clarity of these figures, especially for Fig. 10b.

Answer:

The color scale of Figure 10b will be changed to clarify the figure.

Supplement:

Answer:

I thank the referee for this thorough look which helps to strongly improve the quality of the paper. Therefore, they will be included in the revised version of the manuscript.