Reply to Dr. Valery Melnikov

First of all, authors express their gratefulness to Dr. Melnikov for his valuable comments. Below we give replies.

1. *It is an interesting study of retrieval cloud particles' characteristics from differential reflectivity (ZD_R) and the correlation coefficient (CC) measured with polarimetric radar operating at a frequency of 35 GHz. Two measured radar variables allow retrieving the axis ratio and degree of orientation of cloud ice particles. The approach can be used for polarimetric scanning radars at other frequency bands such as X, C, and S.*

The described retrieval technique is mainly based on the publication of Melnikov and Straka, JTECH, 2013 and publications of Sergey Matrosov about elevation scans with W-band cloud radar with SLDR-mode. The approach given by Melnikov and Straka 2013 utilizes ZDR and RHOHV to estimate axis ratio and angular standard deviation. But it is mentioned there, that it is hard to discriminate between oblate and prolate particles (at least when ZDR < 4dB). In order to solve this problem we use elevation scans (prolate and oblate particles have different angular polarimetric signatures). Indeed, this approach can be implemented at other frequencies but it should be noted explicitly that radar should be able to scan in elevation.

2. *The authors assume horizontal homogeneity in clouds and measure Z_{DR} and CC as functions of the antenna elevation angle. The analyzed cloud in Fig. 14 can be considered homogeneous to some extent, but other examples (Figs. 7, 8, and 17) are not stratiform clouds most likely. I think that homogeneous clouds are rear occasions.*

Please note, that Fig. 14 represents just a singular scan of the cloud shown in Fig 17. The time period of this scan is marked by the red rectangle in Fig. 17. Also note, that one scan takes about 4 minutes, while figures 7, 8 and especially 17 correspond to much longer time scales. Another aspect that should be taken into account is that Fig. 14 represents an RHI scan, while figures 7, 8 and 17 show height-time cross sections and therefore cannot be utilized for judging the cloud spatial homogeneity.

We also want to emphasize, that the cloud homogeneity is not a major assumption of the retrieval algorithm. One of the requirements that cloud should cover more than 50% of the elevation scan (this is stated explicitly in the manuscript). But more important, that we assume that ice particles presented at the same altitude (same ambient conditions) have the same shape even if the cloud is not spatially homogeneous.

3. *Secondly, bulk ice densities of the ice cloud particles remain unknown that make it difficult to estimate their physical axis ratios.*

Please note, that we clearly mention in the manuscript that we do not make any estimates of geometrical axis ratios. Instead, we retrieve the polarizability ratio that is a function of geometrical axis ratio and apparent ice density. We do not make any assumptions about ice density here.

4. *One more unknown comes from a possible mixture of plate-like and columnar crystals. It is of interest to estimate the retrieval uncertainties caused by these unknowns.*

We completely agree with Dr. Melnikov that mixture of different habits can hamper the retrieval technique or at least introduce additional uncertainties. Bailey and Hallett, JAS, 2009 showed that at temperatures warmer than -20 deg ice particles have singular primary shape. At lower temperatures the polycrystalline regime occurs, i.e. a mixture of different shapes can be present. We use spectral polarimetric variables in order to overcome this problem. Particles with different sizes and especially shapes fall with different terminal velocities. Thus using ZDR and RHOHV calculated for one spectral line we can likely avoid (or at least mitigate) the problem of mixing of different shapes in a scattering volume. Note, that in contrast to operational weather radars we do slow (0.5 deg/sec) elevation scans that allows us to have spectral polarimetric variables with Doppler resolution of about 7 cm/s. The validation of the retrieval algorithm based on laboratory studies will be provided in a follow-up publication which is due to be submitted to AMTD until end of October 2015.

5. *It would be very informative if the authors plot vertical profiles of temperature in Figs. 14 and 17 to compare the retrieved particle shapes with the Magono's diagram.*

As mentioned before, the paper about this topic (comparison temperature-shape dependencies with laboratory studies) is under development now and will be submitted for publication soon. Please note, that the aim of the current manuscript is just presenting the 'new' polarimetric configuration and the retrieval algorithm.

6. *Probability of orientation angle was described by a function that is valid for phase difference of correlated signals (eq. 66). This bell-shaped function can be used for the distribution because the true function is unknown, but functions such as Gaussian or Fisher are typically used for that and would be preferable.*

These options (Gaussian and Fisher distributions) were, considered in the preparation phase of the retrieval. But Gaussian distribution cannot be used for wide angle distributions. Gaussian and Fisher distributions cannot represent uniform distribution while the used function can describe different distributions: delta-function (Degree of orientation = 1), mono-modal distribution (0< Degree of orientation <1) with no 'tails' at angles <0 and >180 deg, uniform distribution (Degree of orientation = 0).

7. *Instead of using the degree of orientation it would be preferable to see the standard deviations in orientations expressed in degrees as it has been done by many authors.*

Degree of orientation was introduced quite a long time ago in literature for characterization of canting angles. Within this manuscript it is convenient to use this parameter as it also characterizes the major orientation of symmetry axis.

8. *Averaging in orientation angle θ should be done over the solid angle. Thus, additional multiplier $sin\theta$ should show up in (67)-(68).*

Please note, that the uniform distribution of particles in 'azimuth' (or horizontal plane) is assumed. This has been already taken into account during calculations. 'Azimuthal' and 'elevation' orientations of particles are not correlated. In formulas 67 and 68 we just calculate mean sin^2 and sin^4 of 'elevational' angle (vertical plane). Please note, that $\ominus$ is not a solid angle, $\Theta = \theta\text{-}\theta_0$.

9. *Page 9113, lines 15-16. The authors state that "negative values of $\Delta\varphi_{tp}$ indicate that the horizontal transmission line is shorter than the vertical one". Values of $\Delta\varphi_{tp}$ will also be negative if a wavelength-long waveguide would be added to the current horizontal transmission line*

because of 2pi phase periodicity. So the horizontal transmission line can be longer than the vertical one.

We agree here. Some more details will be added into the manuscript.

10. *Nh and Nv are called the mean noise levels (page 9115, line 17). The mean noise level is typically determined for the whole spectrum. So Nh and Nv in the manuscript are noise levels in a spectral line; this should be stated in the paper.*

In cloud radar community we call Nh and Nv as noise levels. For example see Hildebrand and Sekhon, JAM,1974, Goersdorf, JTECH, 2015.

11. *The standard deviations in Hor and Ver noise are 0.01 and 0.011 (page 9123, line 1). What are the units of these values?*

Please note, that all these values come from uncalibrated power, thus these values are given in arbitrary units. This will be mentioned in the manuscript.

12. *It remained unclear how the standard deviations (SD) of the polarizability ratio and degree of orientation were calculated/estimated. The SDs are determined by the uncertainties in ZDR and CC measurements. It seems to me that the SD have been obtained from the scatter of measured values. This scatter can be caused by natural variability in particles' characteristics. So an analysis of SD caused by the uncertainties in measured ZDR and CC values would be informative for the separation of measurement and natural variabilities.*

For the retrieval we use only data with high SNR (>30-35 dB). Measurement variability in RHOHV and ZDR can be found in light rain when the radar is pointed vertically. Such variabilities for SNR>30 dB are provided in table 2. STDs of RHOHV and ZDR are 4.8*10^-4 and 0.017 dB, respectively. In order to estimate uncertainties in polarizability ratios introduced by measurement variabilities we retrieved those in light rain with SNR in the range from 30…40 dB. Assuming that polarizability ratio of small raindrops should be 1, bias in mean polarizability ratios was in the range from 0.02-0.04 while standard deviation of polarizability ratios was about 0.02. Such values are negligibly low. We will add this information to the manuscript.

Second, as was mentioned earlier we estimate polarizability ratio and degree of orientation for every elevation angle in the range from 30-60 deg separately. Later, using these estimations we find mean and standard deviation of polarizability ratio and degree of orientation for a certain altitude. Thus, variabilities are supposed to be produced by differences in shape and orientation of different populations of ice particles.