Response to the Referee 1 comments

This is a very important study demonstrating a potential of a polarimetric radar for accurate estimation of ice water content in clouds by using a unique experimental setup combining X-band polarimetric radar measurements and in situ microphysical observations on the same airborne platform. It is shown in a number of flights that the polarimetric method grossly outperforms existing IWC-Z relations and that the combination of KDP and ZDR yields better accuracy of the IWC estimate than a use of sole KDP. I am particularly pleased to find out that empirically derived relations IWC(KDP) and IWC(KDP,ZDR) are very close to the theoretical relations derived by Ryzhkov et al. (1998, 2018). I found that the multipliers a1 and a2 in the empirical formulas (12) and (13) (shown in Table 1) are within 6% of the theoretical ones which is remarkable. I think that this should probably be mentioned in the paper. There are several technical deficiencies in the manuscript which have to be addressed before the paper can be recommended for publication.

We would like to thank the referee for these very helpful and constructive comments. We have highlighted the significance of our experimental result as you suggested. We have also addressed the various deficiencies that are pointed out by the referee throughout the paper. Please find our detailed responses to your comments as follows.

(1) I was confused by the definitions of IWCmeas and IWCmod. It took me awhile to realize that IWCmod = (1-ZDR-1)IWCmeas. This is very weird and, I am sure, will confuse other readers as well. I would recommend simply using (1-ZDR-1)IWC instead of IWCmod in the text and labels in Figs. 5 and 12.

We agree with the referee's comment. In the revised manuscript, IWCmod is replaced by $(1_{Z_{DR}}^{-1})IWC$ to avoid any confusion.

(2) I may hypothesize that increasing negative bias in the radar IWC retrieval shown in Fig. 14 could be related to the minimal ZDR threshold of 0.6 dB. I would recommend to decrease the ZDR threshold in the IWC(KDP,ZDR) relation below 0.6 dB and see what happens. Adding large aggregates may disproportionally increase KDP and IWC. At the same time, ZDR decreases and may fall below 0.6 dB. Using values of ZDR lower than 0.6 dB will provide some "boost" for the IWC(KDP,ZDR) estimate.

We thank the referee for this very good suggestion. We have tested and found out that reducing the Z_{DR} threshold indeed improve the estimation bias. However, smaller Z_{DR} threshold increase rms as $(1 - Z_{DR}^{-1})$ comes close to zero. Thus, we selected the threshold at which rms of Kdp-only method and (K_{dp}, Z_{DR}) method are equal. We have revised the text and added figures to include this change.

(3) Number concentration n in Eq (2) is not defined in the text.

The definition and unit of variable n in Eq. (2) is added.

(4) In Eq (5), Kp2 is not equal to 0.177. It has to be the one for water.

We thank the referee for pointing out this error. The dielectric factor of water at 0° C is used for the computation of equivalent reflectivity, $K_p^2 = 0.93$

(5) Page 4. Cross sections σhh,vv are not used in Eqs (1) – (6).

We agree. The radar cross sections are now removed.

(6) Page 5. The approximation (1-ZDR^{-1})IWC ≈KDP is not correct and is not consistent with the value a2 = 0.135 shown in Table 1.

We thank the referee for pointing this out. We actually meant "proportional" instead of "approximately equal".

(7) The reference to Korolev et al. (2018) cannot be found in the reference list.

The reference to Korolev et al. (2018) has been added.

(8) Page 8. Both ΦDP and ΨDP may exhibit discontinuities due to phase wrapping.

We agree. Correction has been made.

(9) Page 9. Two equations IWC(Z) are very different and both differ much from the popular Hogan et al. IWC(Z) equation. Please clarify and comment.

The two equations were derived by fitting a simple power-law curve to the joint frequency distribution of IWC and reflectivity (similar to Eq. (1) in Protat *et al.* (2016) but for measured X-band reflectivity in the HIWC flights). There might be a small bias in the radar reflectivity calibration so the coefficients in those equations could present a small error. However, the IWC(Z) is included just to demonstrate the traditional approach that uses Z can lead to large uncertainties in the HIWC regions.

(10) English usage has to be improved, e.g., data are plural, not single, etc.

We thank the referee for this comment. We have tried to correct language errors and improved the manuscript.

References:

Ryzhkov, A., P. Bukovcic, A. Murphy, P. Zhang, and G. McFarquhar, 2018: Ice microphysical retrievals using polarimetric radar data. 10th European Conference on Radar in Meteorology and Hydrology, 1 – 6 July, The Netherlands, # 40. Available online at: projects.knmi.nl/erad2018/ERAD2018_extended_abstract_040.pdf.

Thanks for this reference. It has been added to the revision.