We thank the reviewer's detailed suggestions and constructive remarks. The authors addressed all of the points made by the reviewer and included a point-by-point response to the reviewer's comments.

Correspondence to reviewer #2:

General response:

1. This study compares two radar data assimilation methods including 3DVAR and LETKF for ICE-POP snowfall cases. It was found that water vapor adjustment is important for the radar data assimilation. However, water vapor and temperature adjustment has been developed for years. What is new for this conclusion?

   ⇒ We think that 3DVAR and LETKF DA methods comparison is quite unique for winter precipitation cases. Most of the previous works are focused on severe weather systems such as thunderstorms, typhoons and squall lines. Large scale, broadly spread stratiform systems are seldom studied but are extensively examined in our research. We conducted additional studies to investigate how the two different methods operates under the same WRF double moment 6-class microphysics scheme (see Appendix A.). The conclusion leads to not just the importance of water vapor but how they interact with different microphysical terms in winter precipitation systems.

2. It is weird to me that the assimilation of radar observation results constant negative increment of snow mixing ratio. Detail descriptions of reflectivity observation operators are needed. A possible explanation is the current radar data assimilation does not adjust the hydrometer variables. In that case, what is the meaning of reflectivity assimilation?

   ⇒ This results from the fact that CTRL run overestimated the amount of snow heavily in the mid-to-upper levels resulting in stronger reflectivity compared to observations. As a result, the DA systems are trying to reduce the amount of snow mixing ratio. Thus, the current radar DA system do adjust the hydrometeor observations. The difference in radar operator between two DA methods arise from the way DA is performed.

   When performing radar reflectivity data assimilation (DA) using 3DVAR, direct DA using an adjoint model or indirect DA method of classifying hydrometeors using the model's temperature field can be used (Xiao et al., 2007 ; Wang et al., 2013). However, since the currently developed adjoint model does not fully implement the cold-rain process, the error of the calculated hydrometeor mixing ratios during DA can be large. Therefore, indirect method is commonly applied as was the case in this study. In addition, in variational DA method, only the variables included in the observation operator changes, so even if hydrometeor mixing ratios are calculated through radar reflectivity DA, the water vapor mixing ratio and winds do not change unless prediction is performed. In RDA, the wind is modified because the radial velocity is assimilated, but the water vapor mixing ratio is not updated, so the dynamic and thermodynamic balance is broken. Therefore, when assimilating 3DVAR radar data, the water vapor mixing ratio was calculated by applying the water vapor mixing ratio observation operator. However, when using the water vapor mixing ratio DA, it should be recognized that the S-band radar is an observation device that cannot observe water vapor, and the equation used for the water vapor mixing ratio DA is an empirically calculated equation.

   Since ensemble members are used in LETKF radar DA, the correlation between each variable can be considered. Therefore, reflectivity can be directly assimilated. Although, the water vapor mixing ratio is not included in the observation operator, through cross correlations the water vapor mixing ratio is also calculated. Accordingly, it is common not to consider the water vapor mixing ratio observation operator in most LETKF DA studies. In general however, the area where high reflectivity (about 30 dBZ) is observed can be considered saturated. But when considering only the correlation between hydrometeor mixing ratios and water vapor, the water vapor mixing ratio may decrease even in the area where high reflectivity is observed. In such cases, even if the mixing ratio of hydrometeors increase through RDA, the surrounding area may be dry and the hydrometeors will not grow and evaporate during the forecast period. Therefore, in order to solve this problem, when radar DA is performed, an observation operator including information on the water vapor mixing ratio must be used.

Minor issues:

1. Line 15-20: "… a lack of a water vapor and temperature observation operator." What does this mean? I believe the radar data assimilation also adjusts water vapor and temperature in LETKF. The cross variable correlation is an advantage for the common used EnKF. On the contrary, the empirical saturation adjustment of 3DVRA will lead to serious overestimation of precipitation. Please see more in Carlin et al (2017).

   ⇒ The authors agree with the reviewer that LETKF can adjust water vapor and temperature with cross correlations and 3DVAR needs empirical adjustment. However, In LETKF DA, the temperature and the water vapor are adjusted during DA cycling, but the increment is too small, and the authors argue that it is not enough. The detail is described in the response to general comments #2.

2. For section 2.2.3, how is the reflectivity data assimilated? Any adjustment of hydrometer variables for 3DVAR and LETKF? Detail descriptions are needed. Most important, for snowfall radar data assimilation cases, I think the direct adjustment of snow mixing ration for radar data assimilation are necessary. Otherwise, any explanations of the improvement of snow are hardly convincible.

   ⇒ The research purpose of this study was to compare two different radar DA (RDA) methods in assimilating winter precipitation over Pyeong-Chang area where intensive observation was performed in 2018. This paper addressed the nature of the differences in radar operator between two DA methods that arise from the way DA is performed. More detail of the radar operators for LETKF and 3DVAR can be found in the Appendix B.

3. About the LETKF, what are the analysis variables?

   ⇒ The LETKF DA system is able to modify the prognostic variable by background error covariance. And these prognostic variables are : 3-dimensional wind, hydrometers (cloud water, rain, cloud ice, snow and graupel/hail) mixing ratio and number concentration, water vapor, pressure and temperature.

   L126–L 127:

For analysis, the system will update the prognostic variables, such as 3D wind, hydrometeor mixing ratio, potential temperature, and geopotential height, using their BE covariances. Besides, the variable-depend horizontal and vertical localization radii are set (Table 1)

4. Line 172: 30 members? But it shows 50 members in Figure 4. How the initial members generated?

⇒ The ensemble members used were 50. The sentence has been modified as follows. The ensemble members are perturbed by the CV3 method, which is done by WRF4v.1.3. The cv3 will perturb some variables such as, stream function, unbalanced velocity potential function, water vapor mixing ratio and unbalanced surface pressure. And then 50 ensemble members are formed.

L 171-172:

In the 3DVAR experiment, RDA is performed by setting CTRL as the initial field at the start of the DA period, but LETKF generates 50 ensembles the first time and predicts each ensemble until the first DA (Table 2).

5. The spin-up period before the radar data assimilation?

⇒ For Case 1, 50 ensemble members start the forecast at 0000UTC 23rd December, 2017 and spin-up for 21 hours. And then conduct the DA at 2100UTC. For case2, the ensemble begin the forecast at 0000UTC 18th March, 2018 and spin-up for 9hours. And then conduct the DA at 0900UTC.

6. Line 195-200: A distance? What value?

⇒ While calculating the FSS, a distance need to be set for the AWS stations validation. Contrast to ETS scores, which is point to point validation, the FSS consider a tolerance distance for model. As we also know that the model has the spatial and time lag comparing to the true observation. Thus, while interpolating the model grids to AWS station location, the nearest model grid point is found first. Next, letting the first point as a pivot point, find another three points and make a square, which enclose the AWS point. Lastly, using inverse-distance method and giving the four points different weight using cubic spline to interpolate the values and calculated the statistics.

7. Line 208-209, "…, depending on the DA method". What does this mean?

⇒ The sentence has been modified accordingly. It means 3DVAR and LETKF are showing similar improvements on snow mixing ratio and wind.

L 210-211:

Regardless of the DA method, increments in wind and hydrometeors show similar patterns.

8. For Figure 6, the final analysis or the first analysis? Any explanation why both LETKF and 3DVAR get negative increment of snow mixing ratio?

⇒ Please refer to general comment response #2.

9. For Figure 9, in what region? Key information should be clearly stated in the figure caption.

⇒ We have corrected the sentence in L196

L 254-257:

Figure 9 shows the difference in the amount of water vapor and hydrometeor mixing ratio vertical profile in the analysis field between experiments. (a), (d) is the difference between LETKF and CTRL, (b), (e) between 3DVAR and CTRL, and (c), (f) between LETKF-3DVAR ***in red area.***

Figure 9 caption:

Figure 9: Vertical profiles of water vapour(black line) and five hydrometeor mixing ratios(cloud: red, rain: yellow, ice: green, snow: blue and graupel: purple line) differences between (a), (d) LETKF and CTRL, (b), (e) 3DVAR and CTRL, (c), (f) LETKF and 3DVAR ***in red area*** *for (a)–(c) 0000 UTC, December 24, 2017, (d)–(f) 1200 UTC, March 18, 2018, respectively.*

10. Please rewrite section 3. Studies have already compared the difference between 3DVAR and LETKF. What is new for this comparison?

    ⇒ Please refer to general comment response #1.