<u>Response to reviewer's comments</u>

We would like to thank the reviewer for the constructive comments and corrections on the paper.

Responses to the specific comments:

Q1) Filling radar gaps is a very important part of hydrologic study. But it is one of the difficult ones since there is not sufficient information inside the gap. The authors' effort to fill gaps using satellite datasets is worthy publication. However, there are existing methods that fill radar gaps using satellite and surrounding radar precipitation estimates (Mahani and Khanbilvardi 2009; Tesfagiorgis et al., 2012; Tesfagiorgis and Mahani 2013). The authors should explain how are their methods different from the rest, other than study area? Which part of your methodology is different? Or did you only come up with a different weight calculation?

A1) The previous studies of Mahani and Khanbilvardi (2009) and Tesfagiorgis and Mahani (2013) used satellite precipitation estimates and surrounding radar precipitation within a moving window. This study also uses satellite estimates and surrounding radar observed precipitation. However, this study has several distinct differences. One of the differences can be found in the merging method. The method calculates optimal weights for merging two datasets over the gap areas based on reference data. This study also develops a precipitation estimation method for the geostationary satellite and a bias correction method. Moreover, interpolated radar precipitation fields over the gap areas are used as one of the datasets to be merged.

Q2) In the abstract, the authors stated that "the results suggested that ...." If the merged product is not better than the satellite product, why don't the authors fill the gaps with bias corrected satellite products without the extra effort of producing a merged product?

A2) Figure 9 presents that correlation coefficients between radar and merged estimates (ρ_{mr}) are typically larger than correlation coefficients between radar and satellite estimates (ρ_{sr}). This result implies that using merged precipitation fields help to estimate more accurate precipitation than using only satellite precipitation over radar gap area. This context was mentioned at the paper (AMTD Page 6310, Lines 21-24). Besides, the radar-estimated precipitation field should be remained intact outside of gap area. The discontinuity will be conspicuously shown when the gap areas are filled with only satellite estimates without using interpolated radar precipitation fields.

Q3) Is the proposed merging method "successive correction"? Successive correction method is a pixel by pixel calculation of the missing (gap) pixel. This method was used to fill gaps (missing pixels) by several authors before (Brandes 1975; Mahani and Khanbilvardi 2009; Tesfagiorgis et al., 2012 and Tesfagiorgis and Mahani 2013). Please cite these works in your methodology and clearly state how your methodology differs from these work. As you mentioned in the paper, you used a maximum distance of 5km for calculation of weights. I am assuming that 5 km is the size of your moving window. Am I right? Please mention that.

A3) The merging weight coefficients are calculated at each pixel. Then the merged precipitation is estimated by pixel by pixel calculation. In the sense that pixel by pixel calculation is a successive correction, the proposed merging method in this study may be considered a successive correction. The previous study of Brandes (1975) applied successive correction method to produce radar calibration field by using rain gauge. As we mentioned before, Mahani and Khanbilvardi (2009) and Tesfagiorgis and Mahani (2013) used satellite precipitation estimates and surrounding radar precipitation within moving window. They utilized the difference between radar and satellite precipitation estimations of surrounding gap (outside of the gap) for generating merged precipitation. This study uses satellite precipitation and interpolated radar rain rate field. Optimal merging weights are then calculated by using the reference data inside of the gap areas. We added these explanations and cited the papers, as recommended by the reviewer, at the revised version of the paper (Page 7, Lines 20 – Page 8, Line 2) as follows:

"The weight coefficients are calculated at each pixel. The proposed method in this study thus is considered a successive correction implying a pixel by pixel calculation of the gap (e.g., Brandes, 1975; Mahani and Khanbilvardi, 2009; Tesfagiorgis and Mahani, 2013). The previous study of Brandes (1975) applied a successive correction method to produce radar calibration fields by using rain gauges. Mahani and Khanbilvardi (2009) and Tesfagiorgis and Mahani (2013) used satellite precipitation estimates and surrounding radar precipitation within a moving window. The studies utilized the difference between radar and satellite precipitation estimations of surrounding gap (outside of the gap) for generating merged precipitation. This study first estimates satellite precipitation and interpolates the radar radar rain rate field over the gap areas using surrounding radar-estimated precipitation.

Optimal merging weights are then determined for the satellite precipitation and interpolated precipitation fields based on the RMSE difference from the reference data."

The maximum distance of 5 km was set to calculate weights in order to generate interpolated radar rain rate field. The interpolated radar rain rate was calculated from surrounding 5 km data. This context was mentioned at the paper (AMTD page 6307, line 8 and 10).

Q4) There are also similar equations among your merging technique and previous studies (mentioned above). For instance, your equation 5 calculates the first estimate for the missing gap pixel using the surrounding information. Brandes originally devised that same exact equation (Brandes 1975). That equation later adopted by Tesfagiorgis and Mahani 2013 for a similar purpose. Explain that very well and cite these work.

A4) We may consider Eq. 5 a typical weighting equation to get an average of the surrounding pixels. The weights for the individual pixels in the surroundings are determined by the distance from the pixel to be interpolated. The calculation of the weight is expressed in Eq. 6.

Q5) Similarly, the authors' calculation of weight (equation 6) is also from Brandes and later adopted by Tesfagiorgis and Mahani 2013 to fill radar gaps. In calculating the weight, you stated that "r is the maximum distance (km), which was set to 5 km in this study." It is up to the authors which value of r to choose. But, my understanding is that r should have the unit of km2. According to previous studies, r controls the degree of smoothing in the exponential weight calculation.

A5) Thank you for the comment. We found it is a typo. Eq. 6 is a form of Gaussian function ($f(x) = A \cdot \exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right)$). Eq. 6 is corrected in the revised version of the paper (Page 7, Line 10) as follows:

$$I_k = exp(\frac{-d_k^2}{2r^2})$$

Q6) Next, the authors merged the satellite with the interpolated radar. While doing this, they calculated RMSE between the satellite and the "reference data". What is your "reference data"? I struggled to understand this part of the methodology. It is not that clear for me. In addition, I thought the authors ultimate goal is to fill radar gaps. If there is reference data *inside the gaps, why didn't use the authors use the 'reference' data to fill the gaps? Or is the "reference" another independent data (other than the satellite and the interpolated radar)? And one major point at this step is that, previous studies considered error (difference between the satellite and the interpolated radar). Taking the difference (error) correction has an additional advantage that helps whenever the rainfall happens inside the radar gap. Why is yours better than the ones that considered error (difference) correction? See Brandes 1975 (equation 7 and 8); Mahani and Khanbilvardi 2009. What would happen if the rainfall falls completely inside the radar gap? The surrounding radar wouldn't help in your cases since the interpolated value from the surrounding pixels will have a value of 0 (but in reality that pixel may be raining). Explain*

A6) The reference data indicates another independent data in this paper. This study used reference data to calculate optimal merging weights. The original radar precipitation field and AWS measurements were used as reference data. Merging with optimal weight calculation based on the original radar data is not possible in practice. We deliberately included the original radar data to test the accuracy of the merging method.

In practice, there is no radar information over the gap areas. The interpolated rain field is just one of the two datasets to be merged. If the interpolated rain field is not as accurate as the other data (satellite estimates), then the smaller weight will be assigned to the interpolated data in merging.

Q7) The other challenge in filling gaps using satellite estimates is 'bias correction of the satellite estimate'. The authors are using radar precipitation estimates to bias correct the satellite product. Am I correct? But inside radar gaps, there is no radar observation. So, how are you correcting the satellite estimate inside the gap?

A7) The bias correction method of Tesfagiorgis et al. (2011) was employed. The method starts with random selection of bias factor, which was the ratio of a radar rain rate and the retrieved satellite estimates at the same time and location. That is, the bias correction is processed outside the gap area and then necessary bias factors for the correction are obtained. The factors are then applied to the satellite estimates over the gap areas.

Q8) Is this paper an introduction of your methodology using artificial gaps? Are you adopting the technique to fill real gap cases?

A8) We set the synthetic gap areas to develop and evaluate the merging method. This method is designed to fill the real gap areas of KMA radar observations. This study is intended to introduce the method.