Anonymous Referee #3

The manuscript presents an analysis of rainfall intensity-duration (I-D) thresholds used for the identification of debris-flow occurrence. Estimation of gauge and radar-based I- D threshold is carried out and compared. The work in this manuscript is very similar to the one carried out by Marra et al. 2014 thus from a methodological point of view there is no significant novelty. However, the authors carry out the analysis in a completely different region with different hydroclimatic characteristics and as such I consider the results to be complementary to what we already know from past studies. Therefore, I consider overall that the results reported in this work add to our knowledge and further highlight the significance of using remote sensing observations for the estimation of debris flow triggering rainfall. I am including below a list of comments/suggestions that can hopefully help the authors to improve their manuscript.

We thank the reviewer for many valuable and constructive suggestions. The followings are our responses to the reviewer.

1. Page 4, L11-25: This last paragraph should be placed in a different section (not the study area and data). You could have a dedicated section to discuss event characteristics. Also in that same paragraph, you mention info that relates to methodology (e.g. identification of individual rainfall event) that should be placed in the methodology section.

   Response: We thank the reviewer for this helpful suggestion. The contents of this paragraph are adjusted according to this comment. Those contents related to event characteristic and identification of individual rainfall event were moved to the section 4 in the revision.

2. Provide a more detailed analysis of the comparison between radar rainfall estimates at DF (debris flow location) and closest-gauge estimates. For example, a graph showing relative error (y-axis) vs distance (between closest gauge and DF) would be informative. Using different colors per event (on such a graph) would also provide some more info. Lastly, it would be interesting to show that for both rainfall intensity and duration, since you are reporting differences in duration as well. Differences in duration, although important for building I-D thresholds, are not frequently explored. I believe adding some more info on this would strengthen the overall analysis.

   Response: We thank the reviewer for the valuable and instructive suggestion. Based on the comment, we compared the relative errors versus the distance. Some metrics describing relative errors were introduced as below:

Factors	Radar estimate at DF location versus rain gauge observation closest to DF location	Radar estimate at DF location versus Radar estimate at the position of closest rain gauge.
Accumulated Rainfall Relative Error (ARRE)	$ARRE_g(i) = \frac{\lvert R_{df}(i) - R_g(i)\rvert}{R_{df}(i)} \times 100\%$	$ARRE_r(i) = \frac{\lvert R_{df}(i) - R_r(i)\rvert}{R_{df}(i)} \times 100\%$
Duration Relative Error (DRE)	$DRE_g(i) = \frac{\lvert D_{df}(i) - D_g(i)\rvert}{D_{df}(i)} \times 100\%$	$DRE_r(i) = \frac{\lvert D_{df}(i) - D_r(i)\rvert}{D_{df}(i)} \times 100\%$
Rainfall Intensity Relative Error (RIRE)	$RIRE_g(i) = \frac{\lvert I_{df}(i) - I_g(i)\rvert}{I_{df}(i)} \times 100\%$	$RIRE_r(i) = \frac{\lvert I_{df}(i) - I_r(i)\rvert}{I_{df}(i)} \times 100\%$

Note. R represents accumulated rainfall for debris flow event, D represents duration for rainfall event, I represents the mean intensity for rainfall event. The variables with subscript df, g and r respectively represent the observation from radar at debris flow location, rain gauge closest to debris flow location, and radar at the position of closest rain gauge.

ARRE, DRE and RIRE are calculated for each debris flow event. Correspondingly, the distance from debris flow location to closest rain gauge is also calculated. Within 10 km range, scatterplots of the ARRE, DRE and RIRE versus distance are drawn in Figure 1.

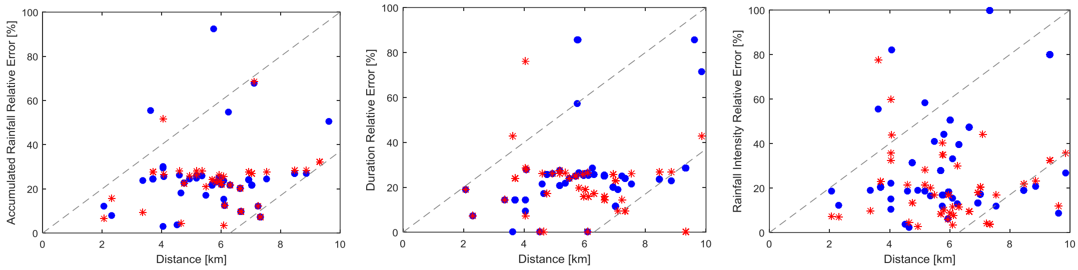

Figure 1. Scatterplot of relative errors versus distance. Blue circle dot represent relative error between radar estimate at debris flow location and rain gauge observation closest to debris flow location. Red asterisk represent relative error between radar estimate at debris flow location and radar estimate at the position of closet rain gauge.(a) Accumulated Rainfall Relative Error, (b) Duration Relative Error, (c) Rainfall Intensity Relative Error.

Concentrating range of relative errors are summarized in Table 1.

Table 1. Concentrating range of relative errors for rainfall sensor closest to DF location

Rainfall sensor closest to DF location	$\frac{\Delta I}{I}$	$\frac{\Delta D}{D}$
Rain gauge	[-0.33, 0.47]	[-0.15, 0.35]
radar	[-0.44, 0.36]	[-0.2, 0.30]

We clarified those in the section 4.3 of revision.

3. Provide also quantification metrics for changes in I-D parameters (α and β).

Response: We thank the reviewer for this suggestion. The parameters of I-D threshold estimated from Scenario III was taken as a reference, the relative errors for α, β between various fitted I-D and the I-D fitted from scenario III were calculated, as shown in the following table. We clarified this in the section 4.3 of revision.

Table 2. Parameters of the identified ID thresholds and relative errors

	α	$\frac{\alpha-\alpha_{S3}}{\alpha_{S3}}\times 100\%$	β	$\frac{\beta-\beta_{S3}}{\beta_{S3}}\times 100\%$
Scenario I	7.62	-24.5	0.67	28.8
Scenario II	8.7	-13.8	0.43	-17.3
Scenario III	10.1	0.0	0.52	0.0
Rain gauges	5.1	-49.5	0.42	-19.2
Radar rainfall estimate at gauge location	5.8	-42.6	0.41	-21.2

*α_{S3}, β_{S3} here equals to α, β estimated from Scenario III, respectively.

Table 1 indicates that improving the accuracy of rainfall estimate could decrease the relative errors of α and β, rainfall spatial uncertainty related to the rain gauge observation lead to underestimation of the I-D threshold for those rainfall events.

4. A professional or native English speaker needs to carefully edit the manuscript for grammatical errors and inappropriate wording (e.g. p10L1 "effectivity" p10L7 "induce" etc)

   Response: We thank the reviewer for this good suggestion. The whole manuscript were read and revised by native English speaker.
5. P5L3: "ensure the rainfall estimation accuracy" is quite a strong statement. Please revise.

   Response: We thank the reviewer for pointing this out. The aim of processing is to improve the rainfall estimation accuracy, the sentence is revised as "improve the rainfall estimation accuracy".(P5L15)
6. P5,L27: Define VIL

   Response: The definition of Vertically Integrated Liquid (VIL) is added in the manuscript as "To discriminate convection precipitation from stratiform based on the composite reflectivity>50dBz or VIL >6.5 kg/m2, where VIL is acronym of Vertically Integrated Liquid water content and it is an estimate of the total mass of precipitation in the clouds."(P6L8)
7. P5,L31-32: "It can be seen that . . .rely on temperature, air dynamic . . .". I don't think that these can be seen from Figure 4 alone. Please revise.

   Respone: We thank the reviewer for pointing this out. We clarified this in the revision as" Impacted by the temperature, air dynamic, particle size and phase are changed along the vertical falling. Figure 4 shows vertical profile of reflectivity varied approximately as three piecewise linear sections".(P6L14)
8. Do you have any justification for the choice of 1.5km as the height threshold for separating the two regions?

   Response: The reason of separating two region is the vertical variation of rainfall rate profile, especially for convective rainfall. Normally, the low scanning elevation PPI is used to estimate ground rainfall rate. Considering the limitation of scanning elevation, station height, and earth curvature, the height from flat terrain is nearly 1.5 km if the radial range is 100 km (normally under maximum detection range) away from radar, even for the lowest elevation of 0.5°. Concerning complex terrain of study area, the elevation almost has to be uplifted to avoid beam blockage when radial distance is over 100 km. Therefore, 1.5 km is set as height threshold for this study to discriminate where is closer to ground and where is higher from ground. The following figure briefly illustrate the radar beam locating height along the radial distance.

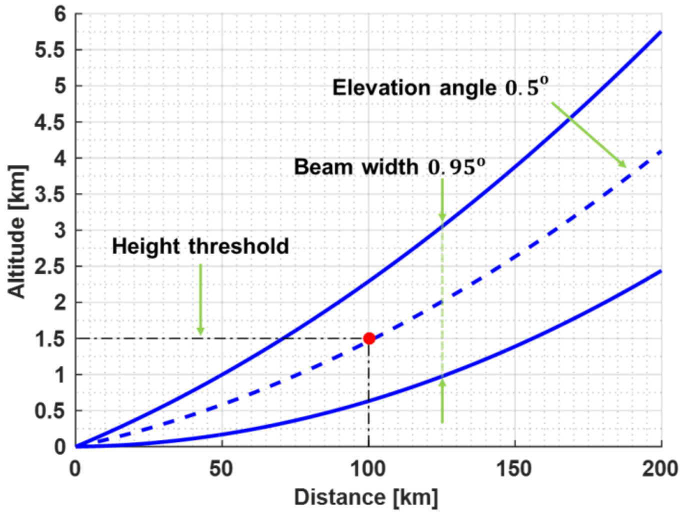

Figure 2. Radar beam locating height along the radial distance

9. P7L24: "between each hour is tiny" perhaps should be "within each hour is negligible". Please check and revise accordingly

   Response: We thank the reviewer for this revision. Changed as suggested. This sentence will be revised in the manuscript as "It is assumed that the variation of the real bias within each hour is negligible" (P8L8)

10. P7L25: "so initial conditions of KF are. . ." I don't believe that the exact numbers for Q, S etc are a result of the previously stated assumption. Revise accordingly.

    Response: We thank the reviewer for pointing this out. This sentence is revised as "the initial estimator for mean field radar rainfall logarithmic bias and it's error variance are assumed to equal their update values which are respectively the $BIAS_{KF}(0)$ and $P_{KF}(0)$.

11. Be consistent with the reporting of equations. Some are in text instead of being numbered as others. Also in P8,L9, you should write log[If(D)] instead of log(I). Revise also the sentence stating "β here accounting for nearly 50% occurrence probability. . ..". It is the intercept, not the exponent that relates to the probability according to the frequentist approach you used.

    Response: Totally agree! log[If(D)] is written instead of log(I) in P8,L9. The modification is made as "where α_{50} , β is the fitted intercept and slope, respectively".(P8L23)

12. P9,L1 and elsewhere: use "scenarios" instead of "scene"

    Response: Totally agree! The "scene" is replaced with "scenarios" in the revision.

13. 13. Equations 14 and 15 have the same formula. Please revise

    Response: Equation 14 is normalized standard error (NSE), equation 15 is normalized mean bias (NMB).We checked those equations as suggested.

14. Define what do you mean by "linear ratio".

    Response: The linear ratio is the slope estimated from linear regression of radar rainfall estimation and rain gauge observation, with the predefined intercept of zero. The linear ratio here is used to evaluate how much average ratio radar-based rainfall is to the observation of rain gauge. The linear ratio approximates to one, if radar-based rainfall estimation is consistent with rain gauge observation. We clarified this in the revision. (P10L3)

15. P10,L10-11: "The PDF estimations reveal that the number of positive difference δ(D) is more than number of negative difference". I am not sure what the point you are trying to make here is. Also, if you think that the distribution of residuals is asymmetric, then you should not fit a Gaussian distribution. This affects also the frequentist approach you followed. Please revise/clarify this point.

    Response: We thank the reviewer for the comment. Perhaps it was not clear in the writing. But we would like to note that although the distribution of residuals is not strictly symmetric for low probability density, the sole peak and high probability density are conform to Gaussian distribution. The related sentences were eliminated in the revision.