Responses to Anonymous Referee #2:

General Comment:

This is a very interesting and clearly written paper on precipitation distribution in a mountainous river basin. Mountains, in particular high mountains in Asia, are the source of freshwater for many people, but the observation of precipitation is far from enough. For example, the first item of Scientific Questions of GEWEX under WCRP is the observation of precipitation. As such, the topic of this paper is within the scope of HESS, and is a hot topic in hydrology. As already described above, the paper is very clearly written, thus easy to follow. Therefore, I basically want to recommend this paper toward publication in HESS. Nevertheless, I would also mention that there are concerns, comments, or suggestions as written below.

Response: We greatly appreciate the reviewer's positive feedback. Our detailed responses are given after each comment (*italics*) below.

Specific Comments:

1) *In the title, abstract and also in any other part of this paper, the authors should clearly mention that the target of this research is annual mean or climatological mean precipitation amount. The authors compared their product with IDW (of gauge-based precipitation) and a TRMM-based product. I can accept this product is better for annual mean and climatological mean. However, IDW and TRMM can provide us short timescale data, such as daily data. This is a major difference between these products against the product which the authors try to show in this paper.*

Response: We thank the reviewer for the valuable suggestion. We change the title as "Remapping annual precipitation in mountainous area based on vegetation pattern: a case study in Nu river" to emphasize the target of this research, and modify the corresponding parts in the manuscript.

2) *It is also recommended to clearly describe that this study is a case study for a specific area, in the title, abstract, and also in other places of this paper. Why I recommend so is described in the following. As shown in Figure 2 and Figure 6, in this target area, precipitation amount is larger for areas of lower elevation. In areas of lower elevation, it is usually expected that air temperature is warmer. It means, in the areas of lower elevation in this study, both precipitation and temperature are better, favorable, for NDVI. I suspect, this the reason why the authors can get a clear positive relationship between precipitation and NDVI. But, this is specific to this particular area. Of course, there could be other similar areas in the world. However, there must also be areas with different characteristics between NDVI and precipitation. Thus, the authors are requested to explicitly describe in the title and the abstract and also in relevant places of the main text that this study is a case study with such characteristics shown in Figures 2 and 6.*

Response: We thank the reviewer for the suggestion. We change the title as "Remapping annual precipitation in mountainous area based on vegetation pattern: a case study in Nu river" to emphasize the specific area of this research, and make it clear in the conclusion that comparison study is needed in other regions.

3) *This comment is a comment following the above comment. Very in general, precipitation is larger if elevation is higher. This is in contrast with what is seen in Figures 2 and 6. But, I need to add to "precipitation is larger if elevation is higher". Such a general tendency is probably true to 2000m or 3000m in elevation. In this regard, "we note that for simplicity, the extra determinants are assumed to have linear relationship with precipitation" is somewhat suspicious because this area has elevation up to 7000m. Is it possible to make a figure in which horizontal axis is elevation and vertical axis is precipitation (and NDVI) using observed precipitation data and NDVI data. There might be a positive relationship between elevation and precipitation up to 2000 or 3000m in elevation, and a negative or flat relationship between elevation and precipitation after it. Also, because NDVI favors large precipitation and warmer temperature (= lower elevation), the response of NDVI is different up to 2000 or 3000m and after it. NDVI-precipitation relation may depend on elevation bands such as lower than 3000m and higher than 3000m (of course, I do not know it would be 3000m or not which changes the relationship), but such an analysis was not done in this study as far as I can see. I think the authors can easily analyze.*

Response: The suggested analysis is conducted in two stages: 1) we examine the relationship between annual precipitation and elevation within different elevation ranges; and 2) we examine the relationship between annual precipitation and NDVI within corresponding elevation ranges as in stage 1, whose results are presented as follows:

1) the relationship between annual precipitation and elevation:

An overall negative relationship is found between precipitation and elevation for the whole elevation range 0–5000 m with a R^2 value of 0.62 (Fig. R2a), whereas there is only unapparent/weak relationship at different elevation bands (Fig. R2b-f). Given the spatial heterogeneity of orographic effects on precipitation (Brunsdon et al., 2001; Daly et al., 2008) and insufficient data of this study, a more thorough investigation of the relationship between precipitation and elevation needs to be conducted with more information that might be available in the future.

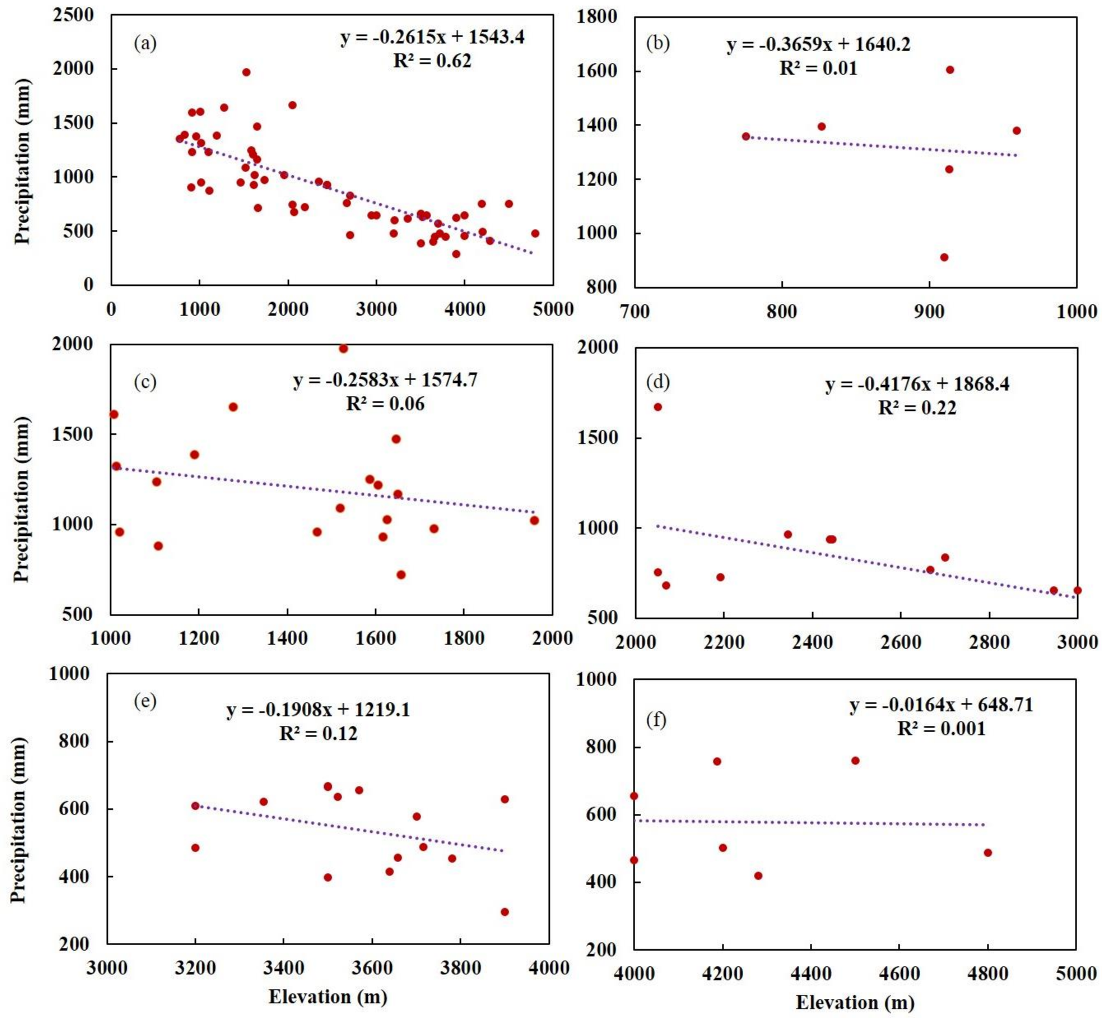

Figure R1 The relationship between mean annual precipitation and elevation at different elevation bands, (a) whole elevation bands; (b) elevation band :<1000 m; (c) band:1000~2000 m; (d) band: 2000~3000 m; (e) band :3000~4000 m; (f) band: >4000 m.

2) the relationship between annual precipitation and NDVI:

Positive precipitation-NDVI relationships are found at different elevation bands (Fig. R3) with the best and worst fitness observed at elevation band 2000~3500 m with a R^2 value of 0.94 and at elevation band 0~2000 m with a R^2 value of 0.62, respectively. By comparing the three regressions at different bands with the global regression, we notice that more significant overestimates of precipitation are observed with the range of lower NDVI values (<0.4) at band 0–2000 m than other three regressions whereas regression at band >3500 m has an significant overestimation of precipitation than other three regressions for higher NDVI values(>0.5).

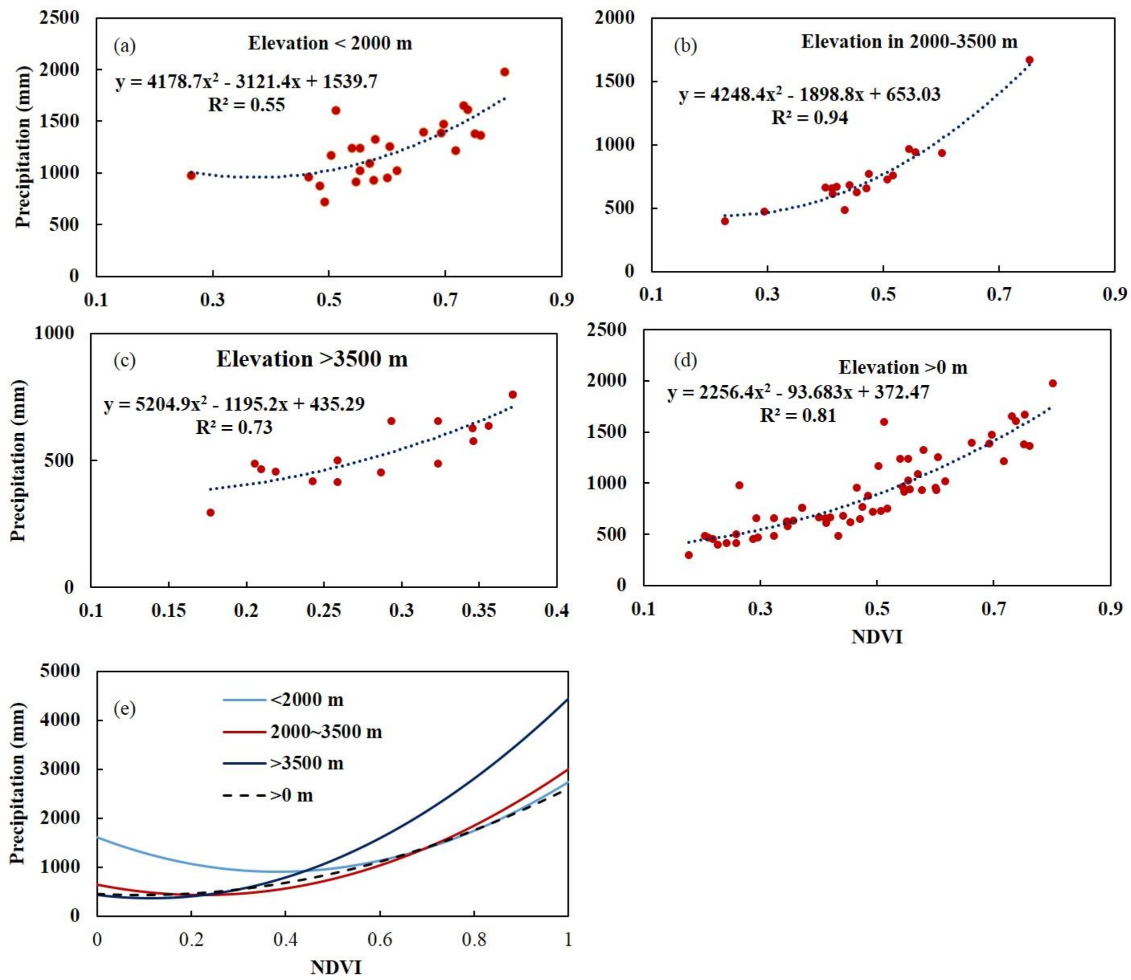

Figure R2 The relationship between mean annual precipitation and NDVI at different elevation bands, (a) elevation band : <200m; (b) band: 2000~3500 m; (c) band: >3500 m; (d) whole bands; (e) comparison of precipitation-NDVI relationship for different bands .

To summarize, an overall negative relationship is found between precipitation and elevation across different elevations in the study region and the NDVI and precipitation demonstrates positive correlations at different elevation bands.

4) *Although target temporal and spatial scales are different, a recent study submitted to HESSD (Beck et al., 2016) provides a globally distributed precipitation data (called MSWEP) in which mountainous precipitation is corrected for gauge under-catch and also orographic effect was introduced by inferring catchment-average P from stream-flow (Q) observations at 13762 stations across the globe. I found mountainous precipitation is somehow well represented in the product by Beck after downloading the data from http://www.gloh2o.org and by making figures of the data by myself. Thus, it is recommended to have discussion in terms of Beck et al. (2016).*

Response: We thank the reviewer for the suggestion and present the comparison between MSWEP product and our product as follows:

Comparison in mean annual precipitation between the gauged measurements and predictions by the MSWEP (Multi-Source Weighted-Ensemble Precipitation, Beck et al. 2016) and TRMM product (Fig. R4) shows that TRMM and MSWEP predicted the precipitation well with an overall overestimation while RME product shows no obvious systematic deviation. The RMSE values for MSWEP, TRMM and RME are 241, 196 and 174 mm, respectively. The possible reason why MSWEP shows no superiority over TRMM in predicting annual precipitation is that few gauge data is available in this region which limited the efficiency of MSWEP method. However, the method in MSWEP does provide insights into the production of high temporal resolution (3-hourly) precipitation, which we believe will be helpful to our future work.

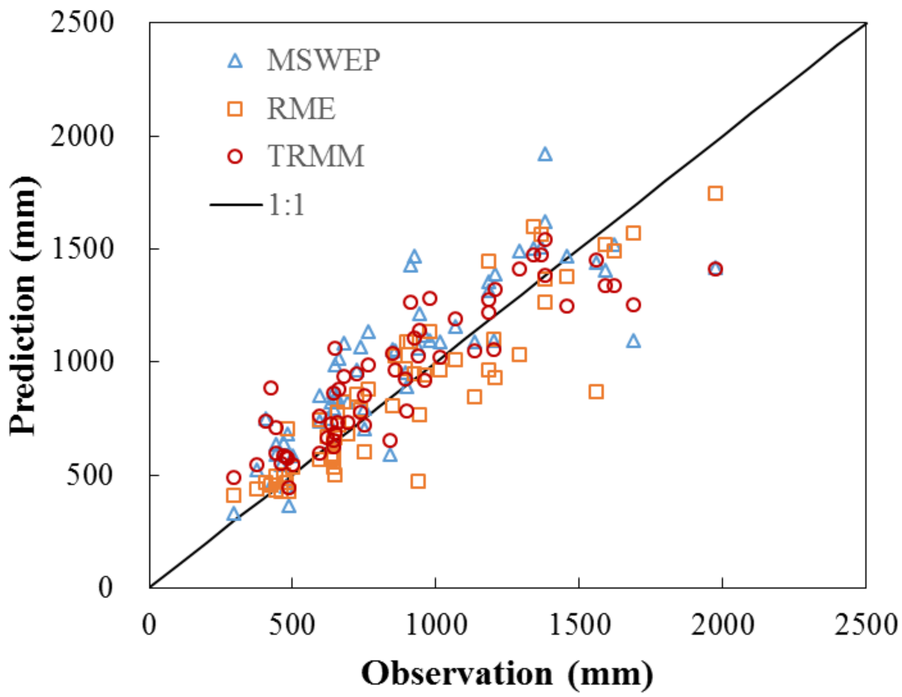

Figure R4 Comparison in mean annual precipitation between the gauged measurements and predictions by the MSWEP, RMM and RME.

5) - A map of sub-basins is better to be provided (for Figure 10).

Response: Added as suggested (Fig. R5).

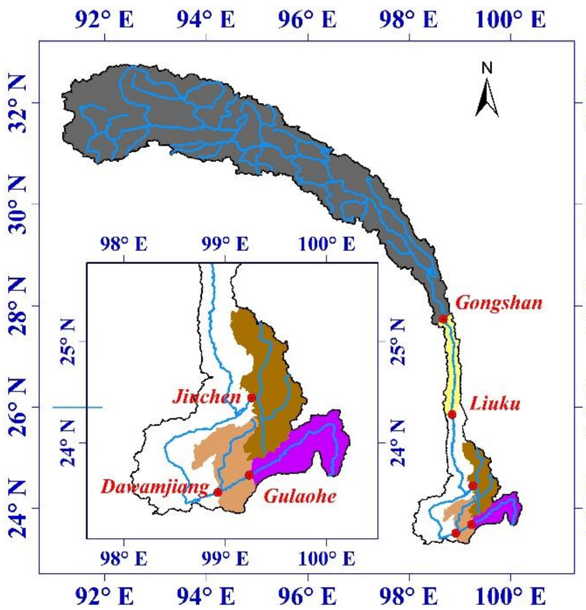

Figure R5 Sub-basins based on hydrologic stations

6) *- I do not think Figure 7 is good to show. I can understand if the authors show the difference between Figure 8 and Figure 6. At least, I would say Figure 7 is awkward.*

Response: Removed as suggested.

7) *- I also suspect that all the areas in Figures 6, 7, 8 are appropriate to show. I mean, there is almost no observation station in the left lower quarter of Figure 2. Then, I suspect whether the values of precipitation amount shown in Figure 6, 7, 8 for the left lower quarter of those figures are enough valid, particularly for the main product of this study and the IDW-based output.*

Response: We agree with that the values of precipitation shown in Figure 6, 7, 8 for the left lower quarter are doubtful because no observation station located in this region. Both RME and TRMM product show this region has large precipitation (>1800mm) and RME gives smaller values than TRMM. As discussed in our manuscript (Line 202-204), the regression model tends to underestimate precipitation as annual precipitation exceeds a certain threshold. We emphasized this conclusion in our manuscript and modified relevant figures.

8) *Very finally, this is probably out of scope of this paper, but I am interested in whether major precipitation season is the same over this particular region. I mean, summer precipitation and winter precipitation (particularly solid precipitation like snow) may have different responses.*

Response: According to our previous study, the distributions of precipitation during the year varies significantly across this region. Fig. R6 shows the distributions of precipitation during the year for 7 stations located in the up, middle and downstream of Nu River. The upstream and downstream have similar distribution of precipitation with major precipitation occurs in summer and little occurs in winter while the middle of Nu River has relatively large precipitation in winter and spring. The solid precipitation mainly occurs in upstream during winter and the amount is small.

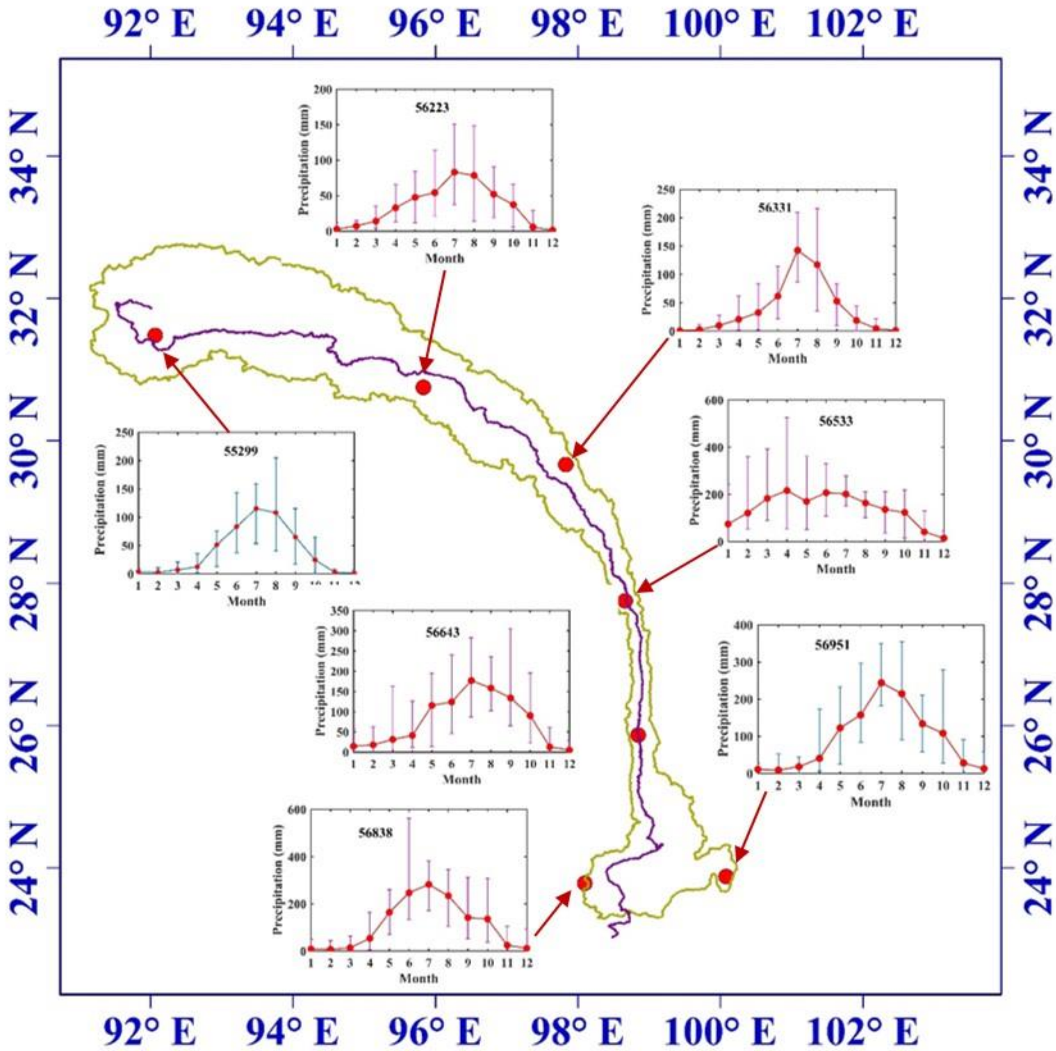

Figure R6 The distribution of precipitation during the year across the Nu River

References :

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Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Curtis, J. and Pasteris, P. P.: Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States, Int. J. Climatol., 28, 2031–2064, doi:10.1002/joc.1688, 2008.

Beck, H.E., A.I.J.M. van Dijk, V. Levizzani, J. Schellekens, D.G. Miralles, B. Martens, A. de Roo (2016): MSWEP: 3-hourly 0.25° global gridded precipitation (1979–2015) by merging gauge, satellite, and reanalysis data, Hydrology and Earth System Sciences Discussions, doi:10.5194/hess-2016–236.