**Reviewer 1**

**Comment**

A few notes on annual rainfall value might help in assessing the typical climate patterns over the study area. Describing trend of rainfall values would be nice. Also, where was the climate data collected? [L91]

**Answer**

Thanks for your comment. In response to your comments, we added sentence in Section 2-1 as follows:

The daily precipitation data was obtained from the Korea Meteorological Administration (KMA) (https://www.weather.go.kr/w/index.do). The annual average precipitation ranges between 1000 mm and 1600 mm. The majority of precipitation occurs in summer.

**Comment**

3.3 Flexible double gamma quantile mapping (F-DGQM) - > bold [L156]

**Answer**

Thanks for your comment. In response to your comments, we modified sub-title in Section 3-3 as follows:

**3.3 Flexible double gamma quantile mapping (F-DGQM)**

**Comment**

I wonder why authors use RMSE to determine delta. For example, several studies use AIC or BIC to find a suitable distribution. However, the authors determined the distribution using only RMSE.

**Answer**

Thanks for your comment. We reselected deltas using normalized values of five metrics instead of RMSE. It is clearly mentioned in the text of the revised manuscript.

AIC and BIC are closer to the optimum as the distribution scale is smaller. Therefore, AIC and BIC may not be suitable for selecting a delta.

**Comment**

Because JSD and KLD evaluated the performance of bias-corrected precipitation, Sections 3-7 should be included in Sections 3-5.

**Answer**

Thanks for your comment. In response to your comments, we modified the Section 3-5 [L216-L252]

**Comment**

As shown in Figure 5, the most suitable deltas are at both extremes. Authors should add a discussion of the determined delta to section 5 or section 4-1.

**Answer**

Thanks for your comment. The delta selection results changed after we changed the data to daily precipitation. Most of the deltas were found to be located in the middle quantiles, described in Section 5 as follows:

The δ of F-DGQM was different at different stations. The middle quantiles were the most selected δ. It means that the suitable δ at a station depends on the scale and shape of the GCM precipitation distribution. Therefore, the determination of δ can influence the estimate of extreme precipitation. It was reasonable to use normalized evaluation metrics to determine two segments.

The F-DDQM showed better performance than F-DGQM because of considering three probability distributions for two individual segments. In F-DDQM, the δ was mainly selected in the median percentile (80%-89%). Further, the selected δ at some stations were specific to 99% and 82%. The Gamma distribution performed the best for two individual segments, followed by Weibull. The results prove that the Lognormal PDF is not proper in analyzing the daily precipitation of South Korea. The performance of F-DDQM was higher than F-DGQM in all evaluation metrics. Furthermore, the performance improvement using F-DDQM was more than F-DGQM at all stations.

**Comment**

As shown in Figure 5, the most suitable deltas are at both extremes. Authors should add a discussion of the determined delta to section 5 or section 4-1.

**Answer**

Thanks for your comments. We have added the following sentences to Sections 4-1 and 4-2 in response to your comments:

The modified Section 4-1 is as follows:

These results showed that F-DGQM performed better than other methods for below δ precipitation because the MD was less sensitive than NSE to extreme values.

The modified Section 4-2 is as follows:

The results indicate better performance of F-DDQM than the other methods for below δ precipitation.

**Comment**

Figure 6: bais - > bias

**Answer**

Thanks for your comments. In response to your comment, we modified Figure 5 as follows:

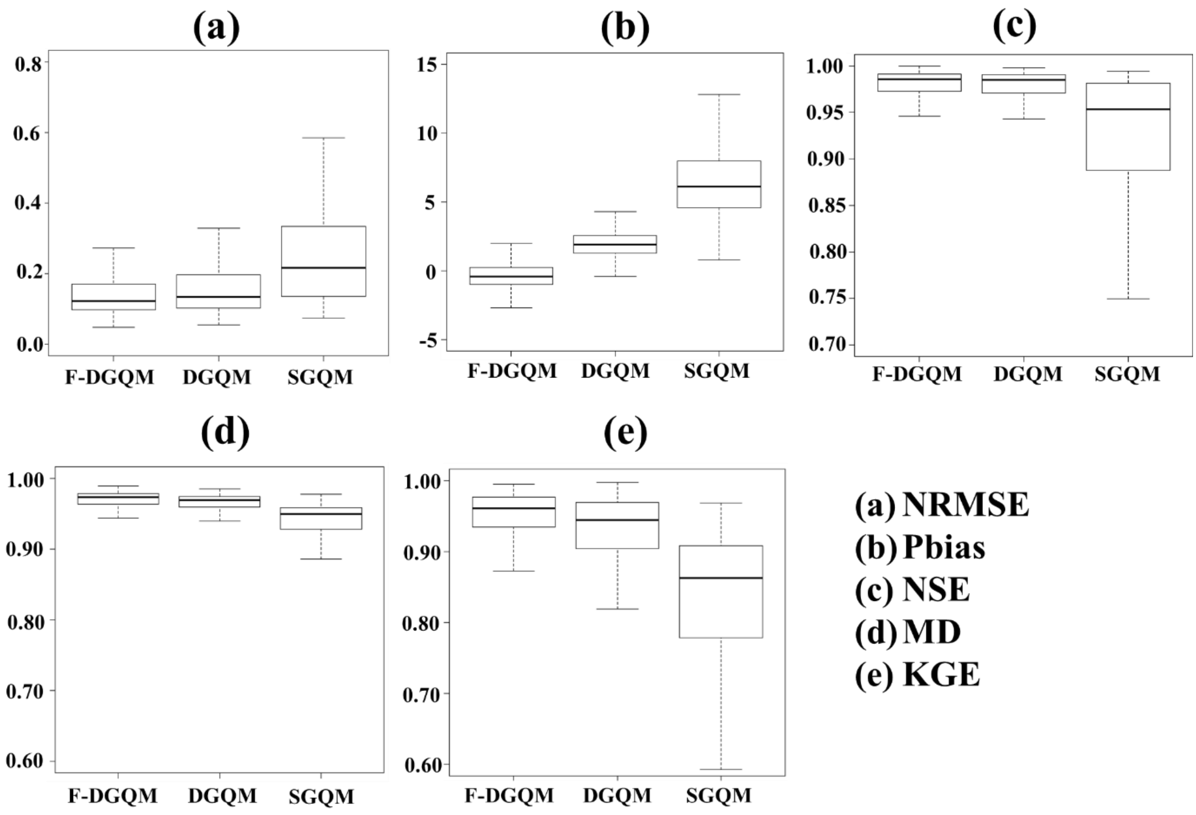



Figure 6. Performance of three QM methods in correcting GCM simulated daily precipitation bias at 22 stations in South Korea.

**Comment**

In the scatter plot of Figure 8, it isn't easy to discern the difference between F-DGQM and DGQM. Therefore, the authors should remove figure 8 as these results have already demonstrated a difference with the evaluation indices. It would also be nice to present an annual time series figure, but it is unnecessary to add it.

**Answer**

Thanks for your comment. We have removed the scatter plots in sections 4-1 and 4-2 in response to your comments.

**Comment**

My comment on Figure 10 is like Figure 5. Authors need to improve their results.

**Answer**

Thanks for your comment. Figure 10 was also changed to daily precipitation, so the delta selection results were corrected. The modified Figure 10 is as follows:

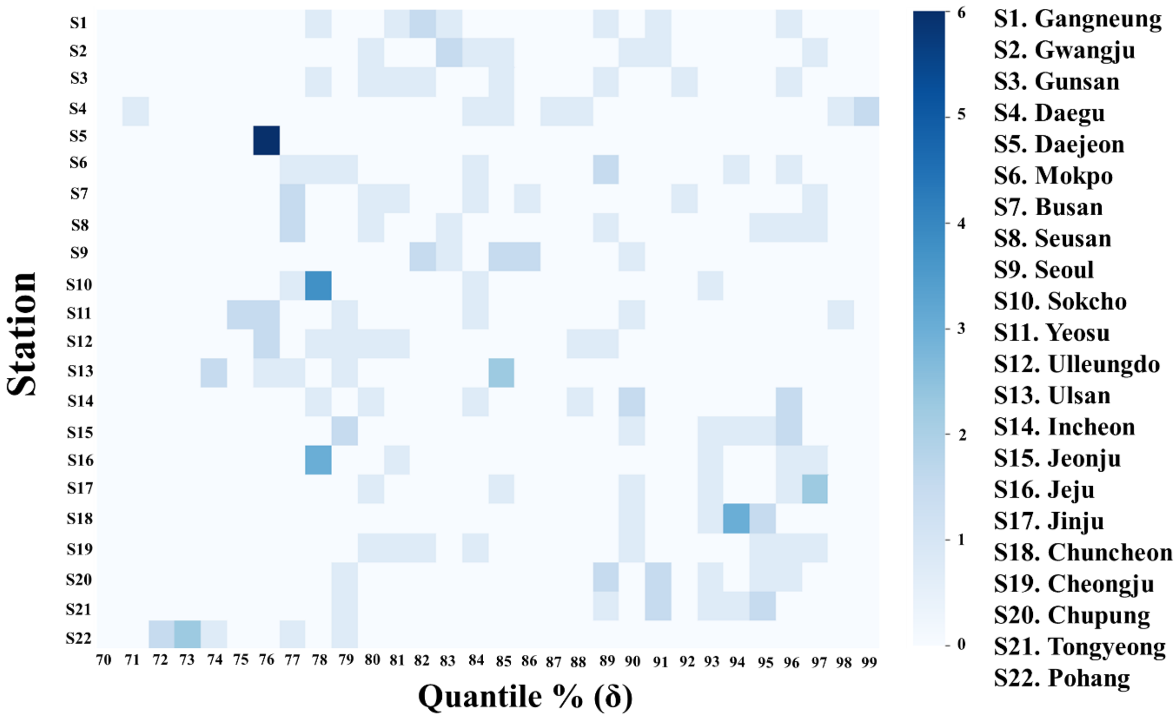



Figure 5. Heatmap showing the number of selected δ for F-DGQM depending on normalized values of five evaluation metrics at 22 stations

**Comment**

My comment on Figure 14 is like Figure 8.

**Answer**

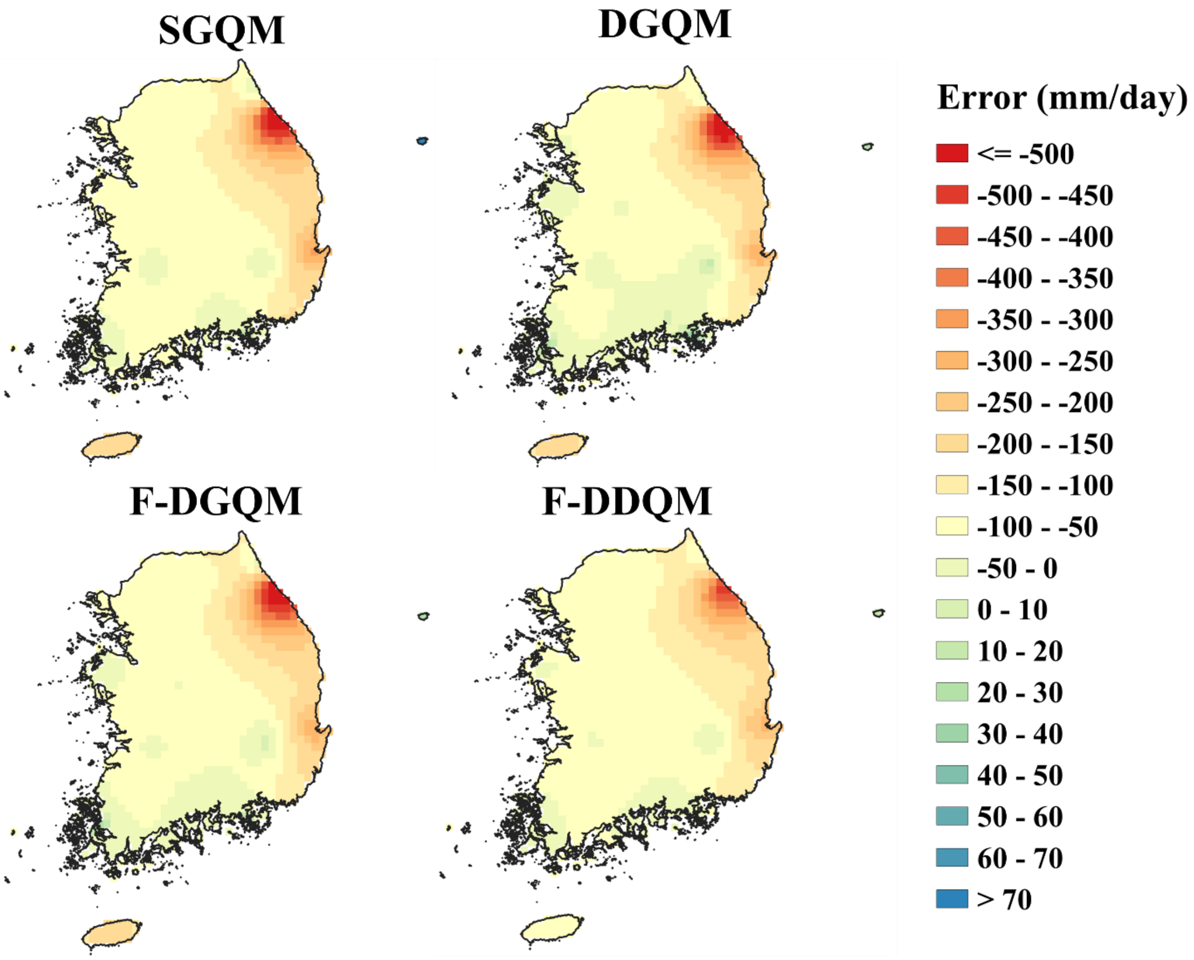
Thanks for your comment. We have removed Figure 14 from Section 4-2 in response to your comments.

**Comment**

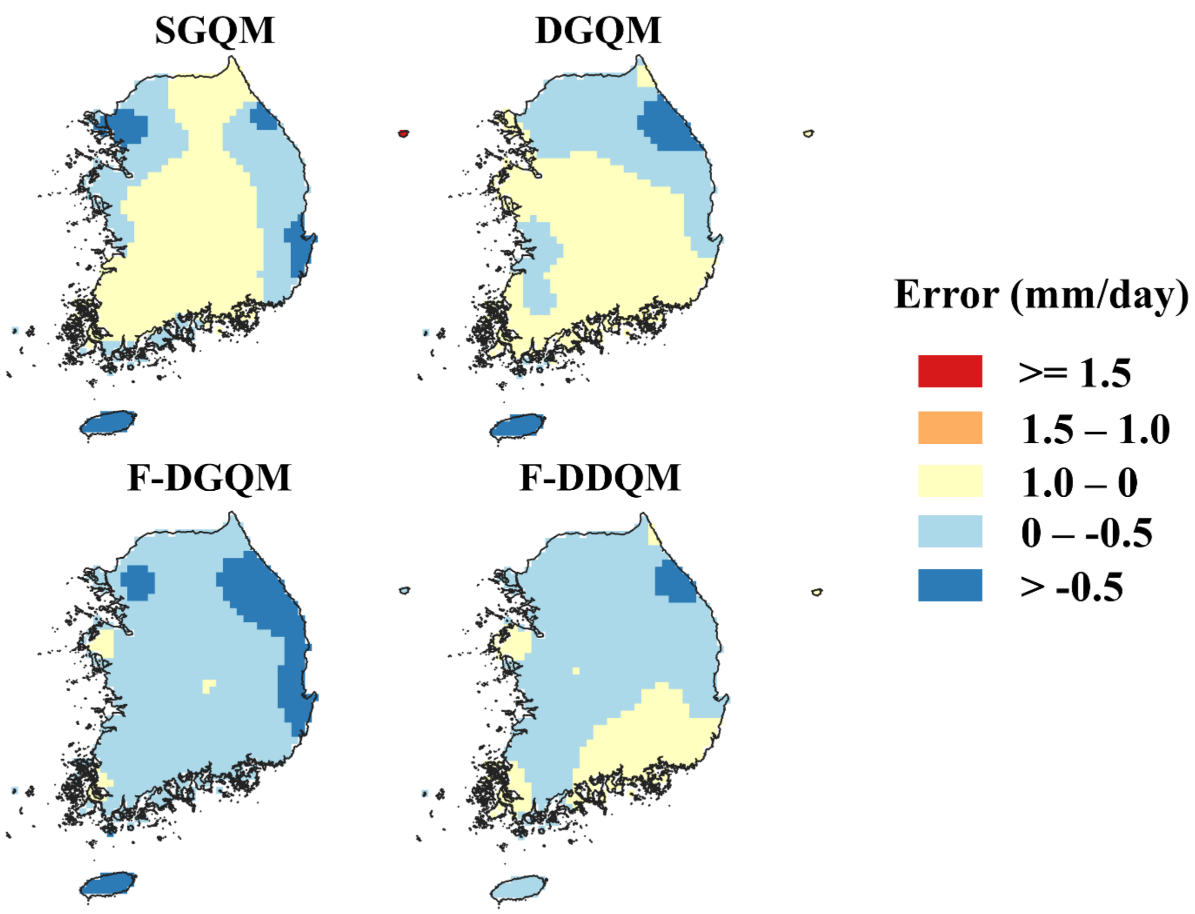
To avoid confusion about what the difference is in Figure 15, the authors need to indicate in the title.

**Answer**

Thanks for your comment. We have modified title of Figure 13 from Section 4-3 in response to your comments.




(a) Maximum




(b) Standard Deviation

Figure 13. Spatial differences in two precipitation metrics between bias corrected and observed data (Observed data - bias corrected data) (a) maximum precipitation; and (b) standard deviation of precipitation for the base period (1985-2014)

**Comment**

The authors should add about this study later in section 6 for the improvement of this study.

**Answer**

Thanks for your comment. We added sentence in Section 6 as follows:

The present study considered only three distribution functions and five evaluation metrics. An attempt can be taken in the future to improve the calibration performance by adding evaluation metrics and distribution functions.

.

**Comment**

The authors need to improve the resolution for the legend in Figure 1.

**Answer**

Thanks for your comment. In response to your comments, we have modified Figure 1 as follows:

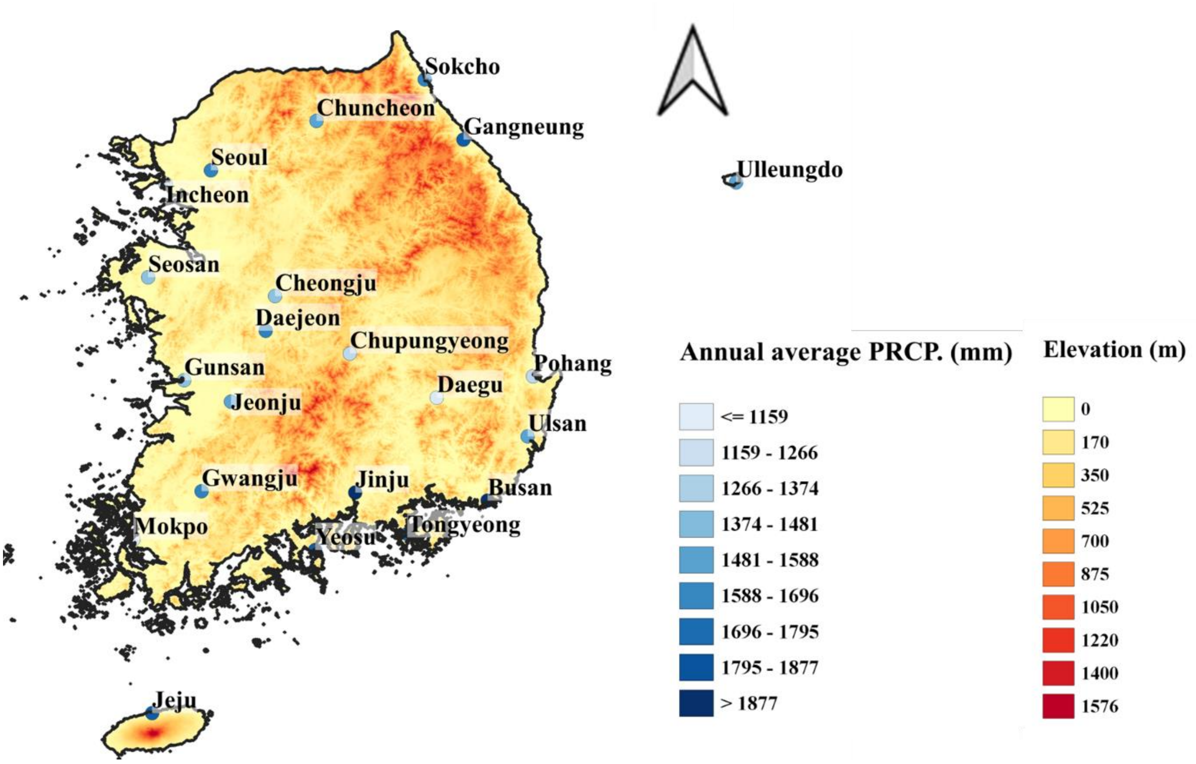



Figure 1. Location of the selected stations in South Korea.

**Comment**

How about moving Figure 1 to Section 2-1? It doesn't fit with section 2-2.

**Answer**

Thanks for your comment. We have moved Figure 1 to Section 2-1 in response to your comments.

## 2.1 Study area

South Korea, located in Asia, lies between Japan and China. The country has four distinct seasons: winter (DJF), spring (MAM), summer (JJA), and autumn (SON). South Korea has mountainous topography in more than half of its total area. The large topographical variability causes significant variations in climate in the country. The daily precipitation data was obtained from the Korea Meteorological Administration (KMA) (https://www.weather.go.kr/w/index.do). The annual average precipitation ranges between 1000 mm and 1600 mm. The majority of precipitation occurs in summer.

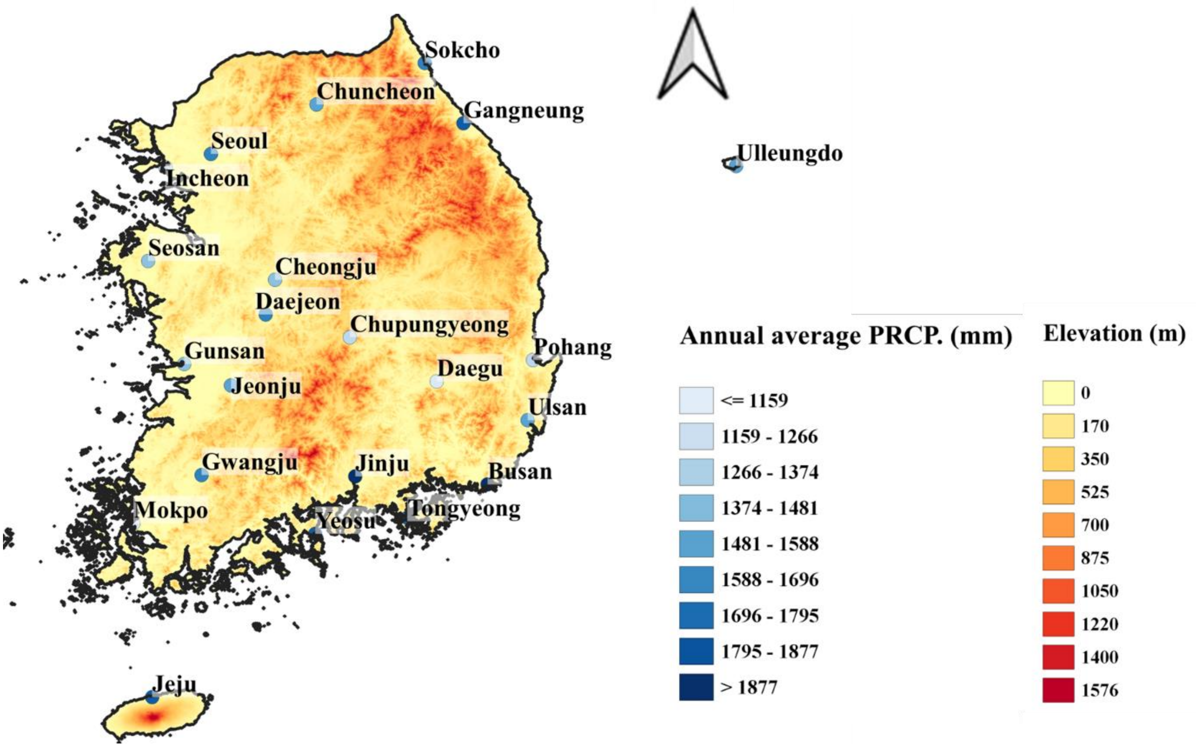



Figure 1. Location of the selected stations in South Korea.

**Comment**

Authors should specify the number of grids in the study area [L132].

**Answer**

Thanks for your comment. We modified sentence in Section 3-1 as follows:

This study used 50 out of 1323 grids GCM grids close to 22 stations for spatial downscaling.

**Comment**

Improve the resolution for Figure 16. Or find another way to show the results clearly.

**Answer**

Thanks for your comment. Figure 16 shows values above the 95th quartile of the GEV distribution. Therefore, the only improvement in resolution is to reduce the quantiles further. Instead, you can confirm the difference between the distributions of the four QM methods and the observed values, as shown in Figure 15. Please understand.

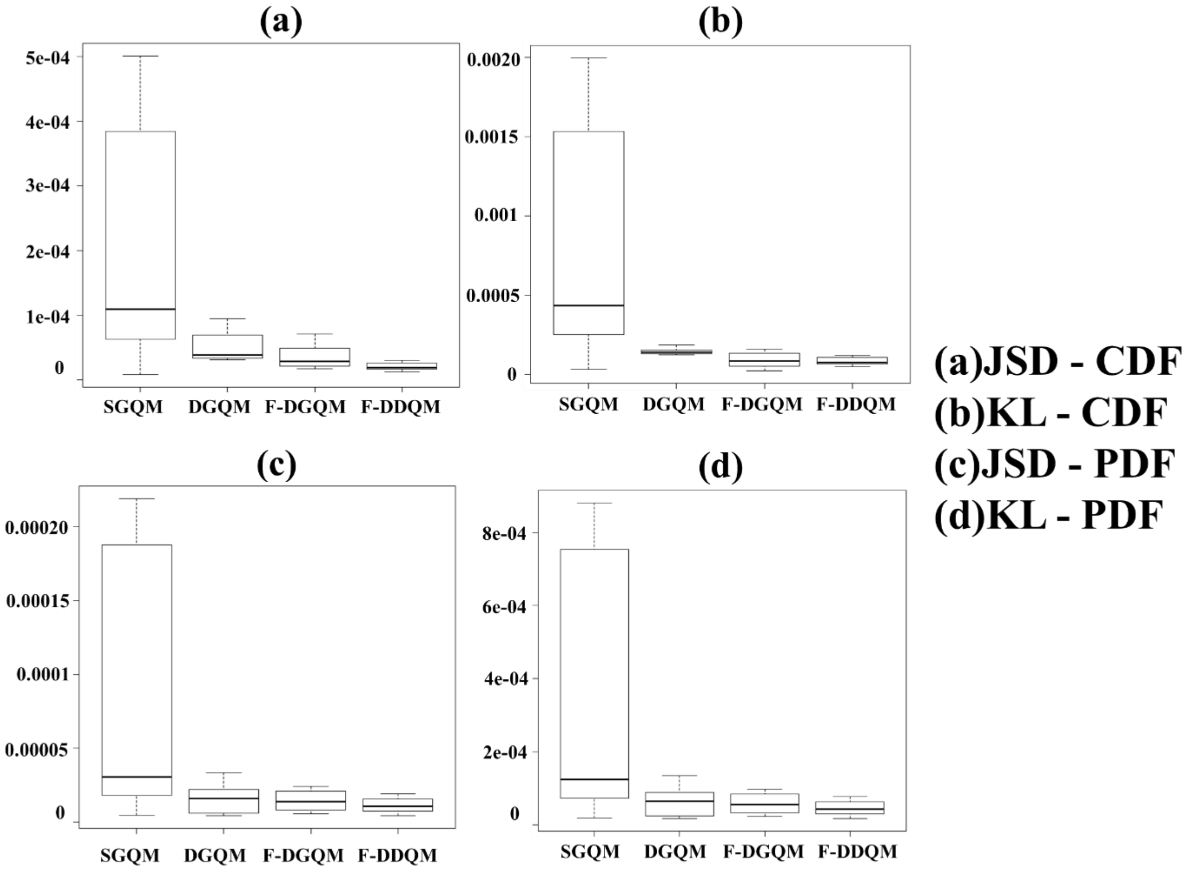



Figure 15. Differences in GEV distribution between the observed and the bias-corrected GCMs' precipitation at 22 stations using KLD and JSD.

**Comment**

Authors should state the limitations of the study in the conclusion. For example, authors may use a variety of metrics.

**Answer**

Thanks for your comment. In response to your comments, we have added the following sentence in the conclusion:

The present study considered only three distribution functions and five evaluation metrics. An attempt can be taken in the future to improve the calibration performance by adding evaluation metrics and distribution functions.

**Comment**

double gamma quantile mapping [L494] - > DGQM

**Answer**

Thanks for your comment. In response to your comments, we modified the following sentence in the conclusion:

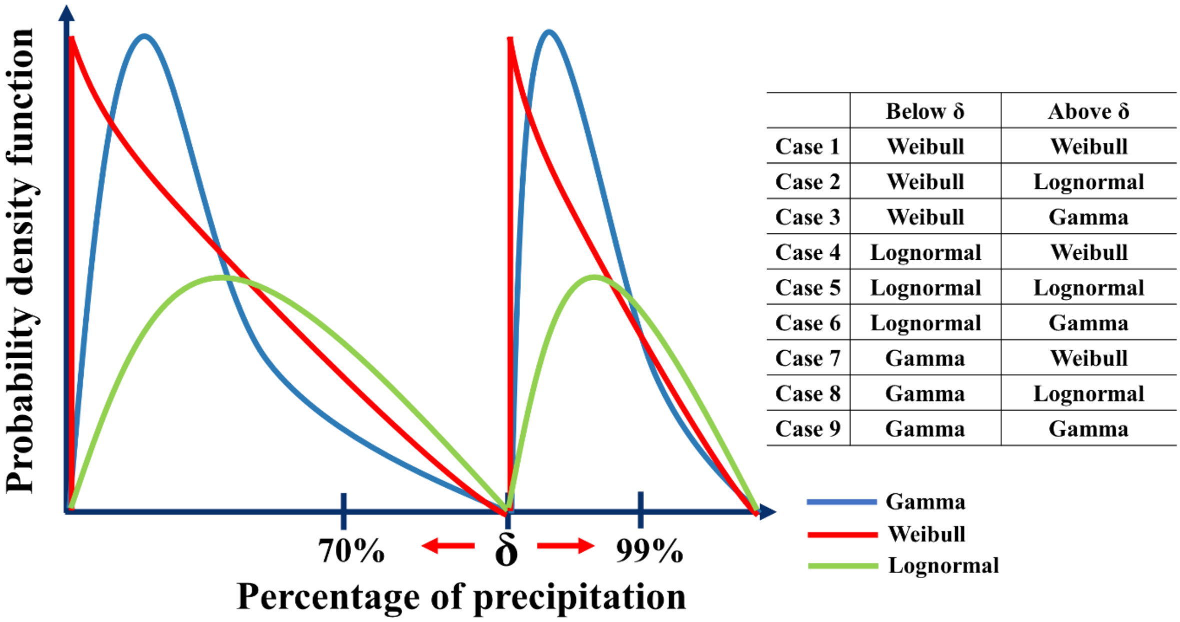
In this study, two new bias correction methods have been proposed to improve the performance of DGQM, F-DGQM and F-DDQM.

**Comment**

The shapes of distributions in Figure 2 and 3 looks same. The shape in Figure 3 can be different because various distributions can be used here.

**Answer**

Thanks for your comment. In response to your comments, we modified Figure 2 in Section 3-4 as follows:




| | Below δ | Above δ |
|---|---|---|
| Case 1 | Weibull | Weibull |
| Case 2 | Weibull | Lognormal |
| Case 3 | Weibull | Gamma |
| Case 4 | Lognormal | Weibull |
| Case 5 | Lognormal | Lognormal |
| Case 6 | Lognormal | Gamma |
| Case 7 | Gamma | Weibull |
| Case 8 | Gamma | Lognormal |
| Case 9 | Gamma | Gamma |

Figure 3. Concept of flexible double distribution quantile mapping (F-DDQM) based on normalized evaluation metrics

**Comment**

L82-84 Check the grammar.

**Answer**

Thanks for your comment. In response to your comments, we modified Sentence in Introduction as follows:

The performance of the proposed method was compared with the DGQM and the Flexible DGQM (F-DGQM) using five evaluation metrics.

**Comment**

The lowest value of delta is 80% in this study. How about considering lower values below 80%?

**Answer**

Thanks for your comment. In response to your comments, we considered quantiles from 70% to 99%, the maximum range that a distribution function can be generated. In addition, the modified results are reflected in the text.

**Comment**

L330-331: Make a paragraph.

**Answer**

Thanks for your comment. In response to your comments, we modified the paragraph in Section 4.2.2 as follows:

### 4.2.2 Evaluation of double distribution quantile mapping

The precipitation of 8 GCMs were bias-corrected at 22 stations using F-DDQM with selected δ and distributions. The performances of the bias-corrected precipitation using F-DDQM, F-DGQM and DGQM at 22 stations based on five evaluation metrics are presented in Figure 10. The median NRMSE of bias-corrected precipitation using F-DDQM was higher than the other two methods. The Pbias showed that F-DGQM and F-DDQM underestimated whereas the DGQM overestimated the daily precipitation. The median Pbias of F-DDQM was closer to the optimal value. The median NSE of F-DDQM was higher than that for F-DGQM and DGQM. In addition, the median MD of F-DDQM was the highest, and the median KGE of F-DDQM was higher than F-DGQM. The results indicate better performance of F-DDQM than the other methods for below δ precipitation.

**Comment**

What is SD in Table 2?

**Answer**

Thanks for your comment. SD in Table 2 is the standard deviation. To help readers understand, we have revised the Table 2 as follows:

Table 2. Errors (mm) in estimating observed precipitation using different bias correction methods.

| Metrics | SGQM | DGQM | F-DGQM | F-DDQM |
|---|---|---|---|---|
| Standard deviation | 0.6 | 0.5 | 0.4 | 0.1 |
| Max | 105.8 | 95.1 | 94.2 | 90.7 |

**Comment**

L448-449 Check the meaning.

**Answer**

Thanks for your comment. In response to your comments, we have modified the sentence as follows:

DGQM has been proposed to solve the problem of dramatically increasing or decreasing extreme precipitation in SGQM.

**Comment**

The future study should be described in the end of conclusion. I want to know the future plan based on this new technique. For example, more distributions can be considered. The dataset for more stations. More GCMs can be used.

**Answer**

Thanks for your comment. In response to your comments, we added the sentence in Conclusion as follows:

The present study considered only three distribution functions and five evaluation metrics. An attempt can be taken in the future to improve the calibration performance by adding evaluation metrics and distribution functions.

**Comment**

The format of references must be checked. ex.) Heo et al. (2019), ...

**Answer**

Thanks for your comment. In response to your comments, we modified the references as follows:

The QM method replaces the quantiles of simulated data corresponding to a given probability with the observed quantile corresponding to the same probability (Cannon, 2008; Piani et al., 2010; Cannon, 2012; Heo et al., 2019).

**Comment**

L189 add “and” after “outputs”.

**Answer**

Thanks for your comment. In response to your comments, we modified the sentence as follows:

In all equations, $X_s$ is the GCM outputs, and $X_o$ is the observed data.

**Comment**

L213 add “and” before “k”.

**Answer**

Thanks for your comment. In response to your comments, we modified the sentence as follows:

where $\xi$, $\alpha$, and $k$ are the location, scale, and shape parameters, respectively. The GEV combines three probability distributions:

**Comment**

L433 add “in” after “boxplots”

**Answer**

Thanks for your comment. In response to your comments, we modified the sentence as follows:

The obtained results for all the GCMs are presented using boxplots in Figure 15.

**Comment**

L434 change “The” by “It” or “This result”.

**Answer**

Thanks for your comment. In response to your comments, we modified the sentence as follows:

This result indicates the better performance of F-DDQM in replicating observed precipitation extremes compared to other bias correction methods.