Quantile-based Bayesian Model Averaging approach towards merging of rainfall products

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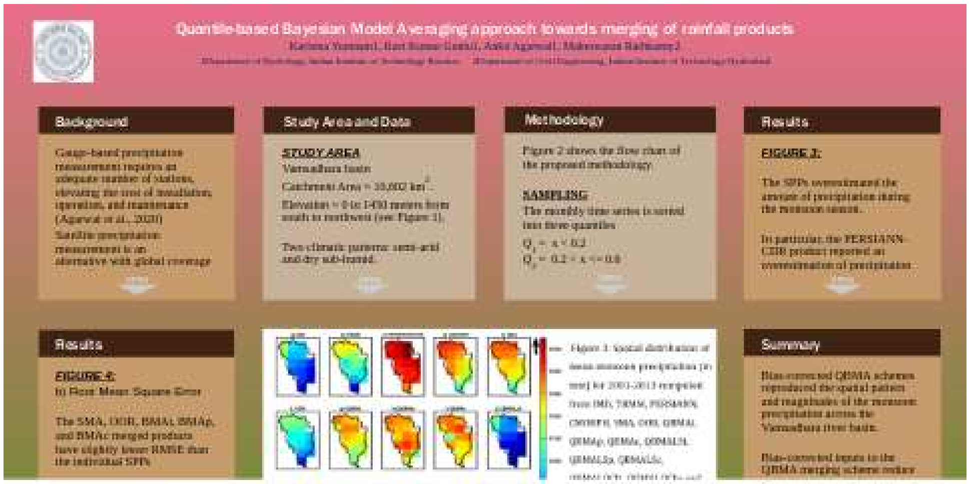
Abstract

Due to the advancement in satellite and remote sensing technologies, a number of satellite precipitation products (SPPs) are easily accessible online at free of cost. These precipitation products have a huge potential for hydro-meteorological applications in data-scare catchments. However, the use of such products is still limited owing to their lack of accuracy in capturing the ground truth. To improve the accuracy of these products, we have developed a quantile based Bayesian model averaging (QBMA) approach to merge the satellite precipitation products. QBMA is a probabilistic approach to assign optimal weights to the SPPs depending on their relative performances. The QBMA approach is compared with simple model averaging and one outlier removed. TRMM, PERSIANN-CDR, CMORPH products were experimented for QBMA merging during the monsoon season over India's coastal Vamsadhara river basin. QBMA optimal weights were trained using 2001 to 2013 daily monsoon rainfall data and validated for 2014 to 2018. Results indicated that QBMA approach with bias corrected precipitation inputs outperformed the other merging methods. On monthly evaluation, it is observed that all the products perform better during July and September than that in June and August. The QBMA approaches do not have any significant improvement over the SMA approach in terms of POD. However, the bias-corrected QBMA products have lower FAR. The developed QBMA approach with bias-corrected inputs outperforms the IMERG product in terms of RMSE.

Quantile-based Bayesian Model Averaging approach towards merging of rainfall products



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BACKGROUND

Gauge-based precipitation measurement requires an adequate number of stations, elevating the cost of installation, operation, and maintenance[1-4].

Satellite precipitation measurement is an alternative with global coverage and at fine spatial and temporal resolutions.

However, these products lack coherence when compared with gauge observations [5-7].

The QBMA approach is developed to merge different satellite precipitation products

STUDY AREA AND DATA

Study Area:

Vamsadhara basin

Catchment Area = 10,602 km^2.

Elevation = 0 to 1450 meters from south to northwest (see Figure 1).

Two climatic patterns: semi-arid and dry sub-humid.

More than 80% of the total annual precipitation (June to September) is received during the monsoon months.

Datasets:

IMD

TRMM

PERSIANN-CDR

CMORPH

METHODOLOGY

Figure 2 shows the flow chart of the proposed methodology.

Sampling

The monthly time series is sorted into three quantiles

$Q_1 = x < 0.2$

$Q_2 = 0.2 < x <= 0.6$

$Q_3 = 0.6 < x <= 1$

Merging

The TRMM, PERSIANN-CDR, and CMORPH products were used for the QBMA merging approach.

The optimal weights were developed for Q_2 and Q_3 using expectation maximization

RESULTS

Figure 3:

The SPPs overestimated the amount of precipitation during the monsoon season.

In particular, the PERSIANN-CDR product reported an overestimation of precipitation amount greater than 400 mm across the river basin.

We found that both the SMA and OOR also overestimated the precipitation amount.

Bias-corrected QBMA schemes reproduced both the characteristics across the river basin.

In particular, the Linear scaling approach with the PERSIANN sampling product has outperformed compared to the other bias-corrected products.

Figure 4:

a) Correlation Coefficient

On comparing only the original precipitation products, the CMORPH product outperformed with a median CC of 0.33, followed by PERSIANN-CDR product.

SMA and OOR also showed comparable median CC over the basin.

The median CC of the merged products generated by bias-corrected QBMA products is almost similar to the QBMAt, QBMAp, QBMAc products

b) Root Mean Square Error

The SMA, OOR, BMAt, BMAp, and BMAc merged products have slightly lesser RMSE than the individual SPPs

The QBMA approach without bias correction does not have any robust results

Bias-corrected inputs to the QBMA merging scheme reduce the error and outperform the SMA and OOR

Figure 5:

The bias-corrected products, in particular, QBMALOCIc, outperformed IMERG based on RMSE and standard deviation across the VRB.

In terms of CC, IMERG is shown to be better than merged products.

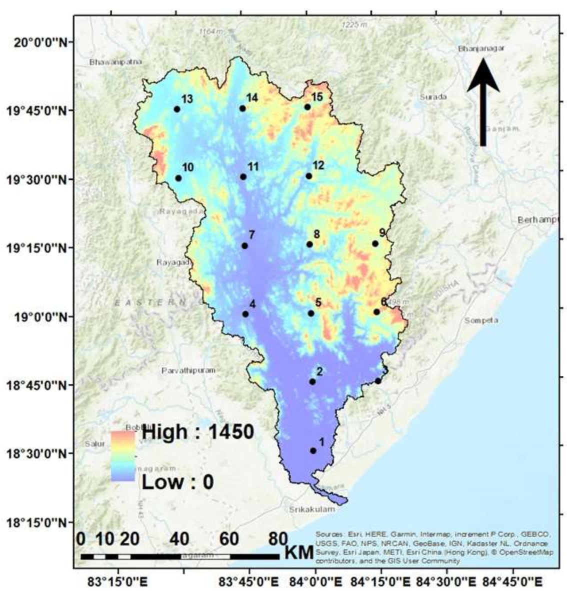
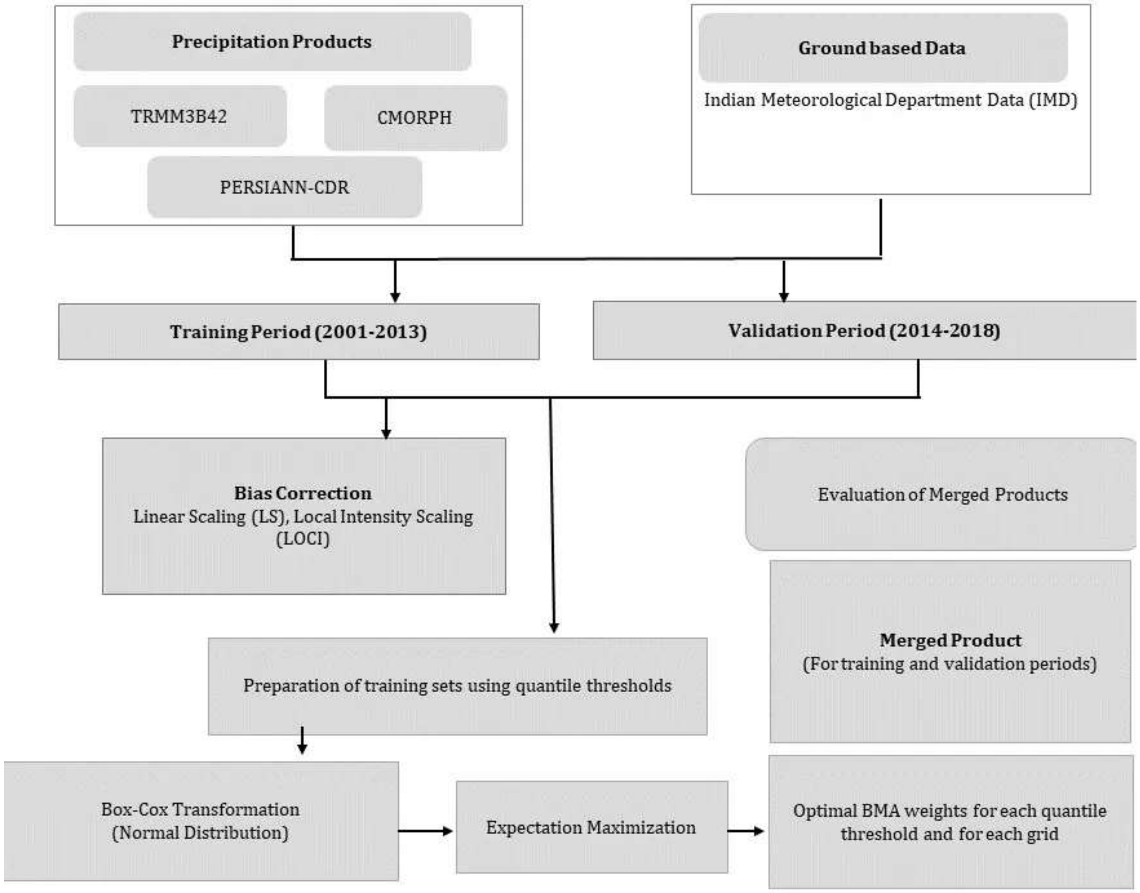


Figure 1: Geographical representation of the Vamsadhara basin. The black dots show the Indian Meteorological Department grid points. The colour bar represents the elevation in meters. The elevation map is prepared by using the Cartosat-1 Digital Elevation Model. First, the cartoDEM tiles were merged into a single raster. Next, pre-processing the merged raster is done using 'fill' and 'con' tools in ArcMap to fill the sinks and remove the negative elevations. The pre-processed raster is then clipped for the study basin.



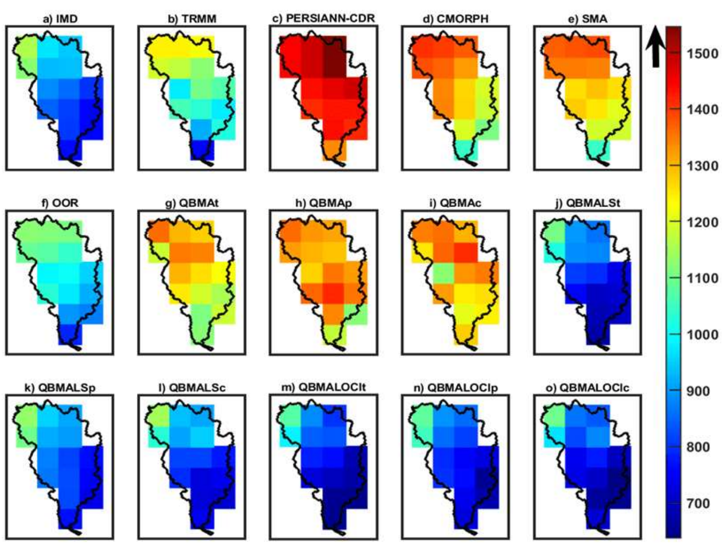


Figure 3: Spatial distribution of mean monsoon precipitation (in mm) for 2001-2013 computed from IMD, TRMM, PERSIANN, CMORPH, SMA, OOR, QBMAt, QBMAp, QBMAc, QBMALSt, QBMALSp, QBMALSc, QBMALOCIt, QBMALOCIp and QBMALOCIc products.

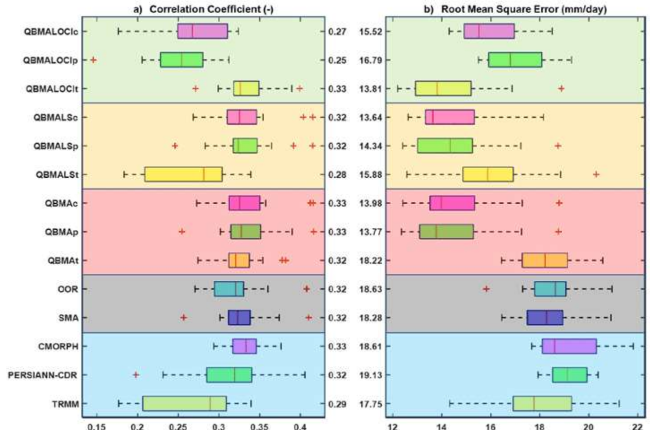


Figure 4: Boxplots of the CC and RMSE during the calibration period (2001 -2013) for the original precipitation products (blue band), merged products using traditional methods (grey), merged precipitation products of QBMA scheme (red band), Linear scaling bias-corrected (green band). The yellow coloured box plots represent TRMM and TRMM sampling-based products, green boxes for the PERSIANN-CDR and PERSIANN-CDR based sampling-based products, and the magenta boxes represent the CMORPH and CMORPH sampling-based products. The median values of a) Correlation coefficient are shown at the right side of the plot, while b) Root Mean Square Error is shown on the left side.

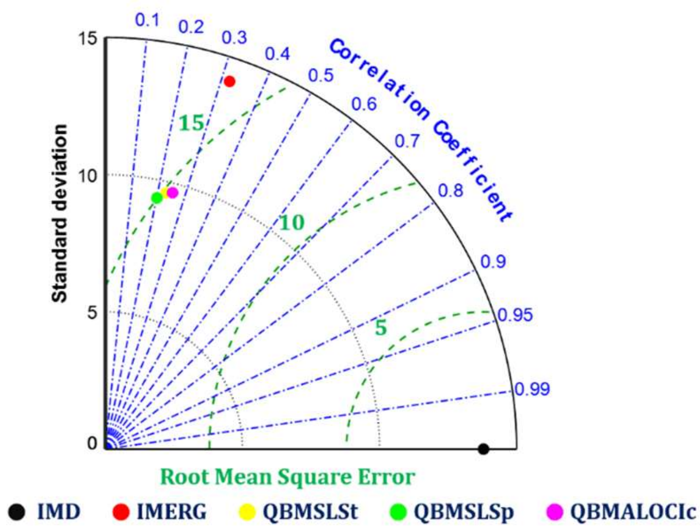


Figure 5: Summary of statistical error metrics of IMERG product (red dot) and three QBMA products: QBMALSt (yellow dot), QBMALSp (green dot) and QBMALOCIc (magenta dot) with IMD (black dot) at 15 independent grids over the Vamsadhara basin during 2014 to 2018. The radial blue dash line indicates the CC, the dashed green coloured arc is the RMSE, and the black dot arc is the standard deviation.

SUMMARY

Bias-corrected QBMA schemes reproduced the spatial pattern and magnitudes of the monsoon precipitation across the Vamsadhara river basin.

Bias-corrected inputs to the QBMA merging scheme reduce the error and outperform the traditional methods

The QBMALSt, QBMALSp, and QBMALOCIc have relatively lower standard deviation and RMSE than the IMERG product

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ABSTRACT

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