ASSESSMENT AND VALIDATION OF REMOTELY SENSED RAINFALL DATA(TRMM) FOR THE STATE OF MEGHALAYA, INDIA.

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ABSTRACT: Rainfall is a dynamic natural process which constantly changes its intensity as it passes over an area. Rainfall traditionally is measured using rain gauges at ground stations but due to the advancement in remote sensing technology Rainfall data can be obtained using satellite data. The study was conducted to assess the spatiotemporal accuracy and reliability of remotely sensed gridded rainfall data with rain gauge data for the state of Meghalaya. The remotely sensed precipitation data was used from the archives of the Tropical Rainfall Measuring Mission (TRMM).The Rain gauge data were obtained from seven Rain gauge stations spread across the state were used to assess and evaluate the TRMM gridded data. The representative area for each Rain gauge station was delineated using Thiessen polygon method. The TRMM rainfall data were extracted for each delineated area and compared with the respective area weighted rainfall from each rain gauge station. The correlation analysis was done using annual, seasonal and monthly data for last ten years (2007-2016). The results show that TRMM data followed the trend of rainfall (highs and lows) as apparent in rain gauge data at the monthly time step for the state of Meghalaya, mostly for the years of analysis. The TRMM data can be a viable option to analyze rainfall trend for Meghalaya, particularly in those areas where the density of rain gauges are not good enough to capture the spatial variation in rainfall.

1. INTRODUCTION

The state of Meghalaya receives the maximum amount of rainfall in India, recording an average of 11,500 mm of rains a year (Department of Agriculture, 2017). For various hydrological and agricultural purposes, it is critical to have accurate rainfall measurements in the state. The rainfall in Meghalaya is normally measured by rain gauges with one rain gauges station in each of its seven districts operated by the Department of Agriculture, Government of Meghalaya.

The present study focuses on evaluating a gridded remotely sensed rainfall data for the state of Meghalaya for last ten years (2007-2016). Meghalaya has been taken under study due to the reason that it receives heavy rainfall which spatially variable in nature. Accurate estimates of rainfall are the need to the hour in Meghalaya that can be used in hydrologic modeling to be able to predict storms and floods in time as well use the information in agriculture. The region is mainly composed of a number of hills and plains. The Garo, Khasi and Jaintia hills are of greater importance because they trap the vapor within their region and very heavy rainfall occurs in that region. Thus, the region has rich vegetation and the effect if slight variation in rainfall will be critical for the ecosystem of the region. Also, this area has not been taken under study earlier, which makes it first of its kind. Hence the present study was undertaken with the following objectives:

- Transform the point measurements of rainfall (from rain gauge) to spatial data using Thiessen polygon method (area weighted estimates of rainfall).
- Compare and assess the accuracy of the remotely sensed rainfall data obtained from TRMM (Tropical Rainfall Measure Mission) with respect to ground-based data (area weighted estimates of rainfall from rain gauges).

2. STUDY AREA

The present study involves in assessing and validating remotely sensed gridded rainfall data for the state of Meghalaya, India. Meghalaya emerged as a full-fledged state within the union of India on 21st Jan 1972. Meghalaya is spread over an area of 22, 429 square kilometers, and lies between 20.1° N and 26.5° N latitude and 85.49 °E and 92.52 °E longitude.

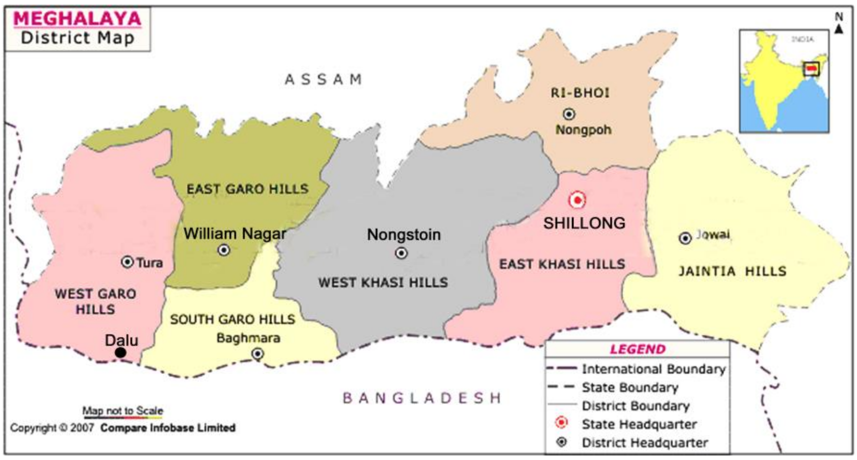


Figure 1: Study Area Map (Meghalaya).

2.1 Climatology & Physical Features

The State enjoys a temperate climate. It is directly influenced by the South-West Monsoon and the northeast winter wind. The four seasons of Meghalaya are: Spring - March and April, summer (Monsoon) - May to September, autumn -October and November and winter - December to February (Department of Tourism, 2017)

The state of Meghalaya extends for about 300 km in length and about 100 km in width. It is bounded on the north and east by the state of Assam and on the south and west by Bangladesh. Meghalaya is divided into Seven Districts and they are "East Khasi Hills", "West Khasi Hills", "Jaintia Hills", "Ri Bhoi District", "East Garo Hills", "West Garo Hills" and "South Garo Hills".

3. DATA UTILIZED

The data utilized in the present study included the TRMM monthly rainfall grids which are designated as '3B43' for the period 2007 - 2016. To assess and validate the TRMM data, ground-based measurements of rainfall from seven rain gauge stations were also acquired. Each of the dataset utilized in the present study is discussed in the following paragraphs.

3.1 TRMM Data

For the present analysis, TRMM 3B43 data set is used which is for the monthly accumulated rainfall in millimetres. The 3B43 dataset of TRMM is executed one per calendar month to produce the single, best estimate precipitation rate and RMS precipitation error estimate by combining the 3 hourly rainfall data. (Nasa, 2017).

Table 1: Basic specifications of the evaluated TRMM data sets.

Data set	TRMM_3B43
Temporal resolution	Monthly
Horizontal Resolution	0.25 degree x 0.25 degree
Data Set Version	7
Parameters	Precipitation Rate
Spatial coverage	50◦ N–50◦ S

3.2 Rain Gauge Data

Rain gauge data were used in the present study to assess and validate the TRMM data. Rainfall gauge station was selected from each from seven districts of Meghalaya. Rainfall data from each selected station was obtained on a monthly time-step for the period 2007 - 2016. The Rain gauge data were collected from the web portal of "Department of Agriculture, Government of Meghalaya", and from "India Meteorological Department, Government of India".

Table 2: Selected Rain gauge Stations for Meghalaya for 2007-2013.

S.NO.	STATIONS	District	Location	
			Latitude	Longitude
1	Rymphum	Jaintia hills	25.4538	92.2057
2	Vegetable Research Shillong	East Khasi Hills	25.5656	91.8947
3	Nongstoin	West Khasi Hills	25.5200	91.2700
4	Umsning	Ri-bhoi	25.7529	91.8945
5	Sangsanggiri Tura	West Garo Hills	25.4833	90.2000
6	William Nagar	East Garo Hills	25.5314	90.5920
7	Baghmara	South Garo Hills	25.1935	90.6346
8	Jowai*	Jaintia hills	25.4509	92.2089
9	Nongpoh*	Ri-bhoi	25.8699	91.8337

*Stations used in place of Rymphum and Umsning for the period 2014-2016 , due to unavailability of rain gauge data at that district.

Figure 2: Selected Rain gauge stations for the years 2007-2013.(From 2014-2016 stations at 'Jowai' and Nongpoh were considered in place of 'Rymphum' and 'Umsning' respectively , due to unavailability of Rain gauge data at that particular area.)

4. METHODOLOGY

The methodology followed in the present analysis included estimating average rainfall for the entire state of Meghalaya using rainfall data from the respective rain gauges. The average data was estimated using the simple arithmetic mean method and by converting the point measurements of rainfall from rain gauges to a spatial data using Thiessen polygon method. TRMM data was extracted for the individual areas (delineated by Thiessen Polygon method) representative of each selected rain gauge station. The evaluation of TRMM data was performed by comparing its data with concurrent rain gauge measurements on station level and for the entire state of Meghalaya. The detailed methodology followed in the present study is summarized in the following paragraphs.

4.1 Average Rainfall from Rain Gauge Stations

The following methods were used in this study for estimating average rainfall for the entire state as well as for the areas represented by each respective rain gauge station:

- Arithmetic mean method
- Thiessen polygon method

4.1.1 Arithmetic Mean Method

This method can be used for the storm rainfall, monthly or annual rainfall average computations. However, use of this method has decreased because it does not provide representative measurements of rainfall in most cases (Chow, 1964). The average rainfall using arithmetic mean method is estimated using the following equation:

$$\bar{P} = \frac{1}{N}\sum_{i=1}^{N} P_i \quad (1)$$

Where P_i: rainfall at the i^{th} rain gauge station, N: total no of rain gauge stations

4.1.2 Thiessen Polygon Method

Rainfall is spatial-temporal phenomena where it varies with space and time. Additionally, rainfall also varies in intensity and duration spatially. Therefore, an area-weighted mean of rainfall is considered to be a better representation of average rainfall over an area as in the present study.

The Thiessen polygon (THI) method assumes that the estimated values can take on the observed values of the closest station. The THI method is also known as the nearest neighbour (NN) method (Nalder et al., 1998). The method requires the construction of a Thiessen polygon network. These polygons are formed by the mediators of segments joining the nearby stations to other related stations.
In the present analysis, Thiessen polygons were used to delineate the area represented by each rain gauge station. The Thiessen polygons were constructed using the ArcGIS software by providing it the spatial locations of each rain gauge station and the state boundary.

$$\bar{P} = \frac{1}{A}\sum_{i=1}^{N} A_1\, P_1 \qquad (2)$$

Where P_i: rainfall at the i^{th} rain gauge station, Ai: Polygon area for i^{th} Rain gauge station, N: total no of rain gauge stations, A: Total area

This method assumes that any point in the watershed receives the same amount of rainfall as that measured in the nearest rain gauge station. Here, rainfall recorded at a gauge can be applied to any point at a distance halfway to the next station in any direction.

4.2 Assessment of TRMM Data

The monthly rainfall obtained from TRMM data was evaluated and validated by comparing the data with concurrent rain gauge measurements. The comparison was performed to evaluate how well the TRMM data followed rain gauge measurements at individual station level both monthly and annual for the entire period of the study (2007 - 2016). Additionally, the comparison was also made for the entire state's mean monthly and annual rainfalls.
Comparison is the assessment and quantification of the relationship between a matched set of estimated and observed data, examining resemblances or differences. These observations are quantitative (Stanski et al., 1989).

5. RESULTS AND DISCUSSION

The present study was conducted to assess remotely sensed gridded rainfall data for the state of Meghalaya. Monthly rainfall data obtained from radar remote sensing for the period 2007-2016 was analysed and compared with the concurrent rain gauges measurements. The results obtained in the present study are summarized and discussed in the following paragraphs under their respective headings.

5.1 Average Rainfall from Rain Gauges

The average monthly rainfall for the entire state of Meghalaya was estimated using Arithmetic Mean and Area Weighted (Thiessen Polygon) methods respectively. It is apparent from the results presented in figure 3 that the monthly average data estimated from both the methods are close and overall has low differences (4.43% across the 2007-2016 periods). The largest difference was apparent for the month of February (16.36%) with the least being in September (1.15%). The period of highest rainfall in Meghalaya includes the months of June, July, and August with November, December and January being the months in which lowest rainfall is received.

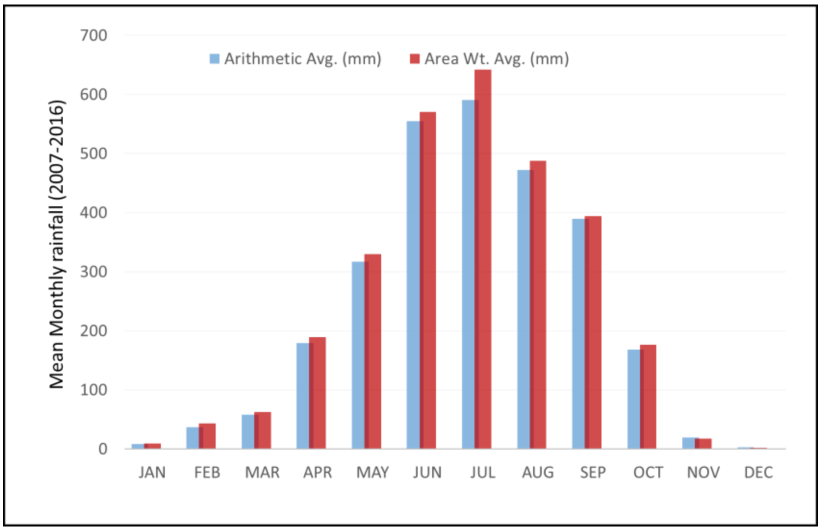


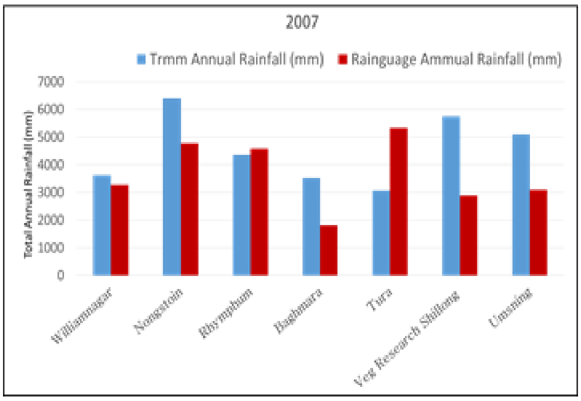
Figure 3: Distribution of Mean Monthly Rainfall for Meghalaya (2007-2016).

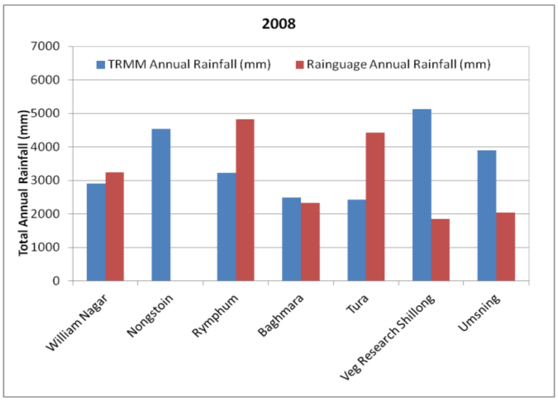
5.2 TRMM and Rain Gauge Data Comparison

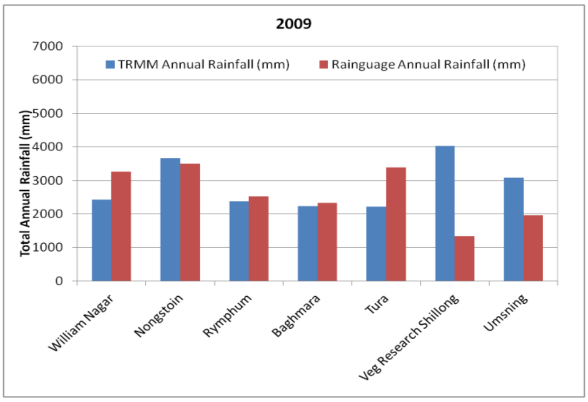
5.2.1 Rain gauge Station Level

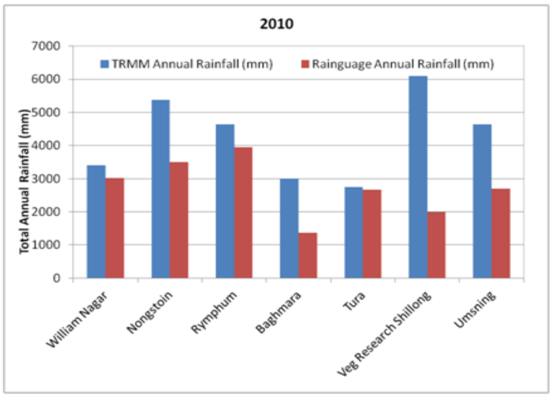
TRMM rainfall data was evaluated by comparing it with the concurrent rain gauge data. The figure 4 presents the comparison performed for individual stations for each year. The rainfall records at the Nongstion and William Nagar rain gauge stations for 2008 and 2012 respectively were unavailable, hence not included in the respective graphs (Figure 4).

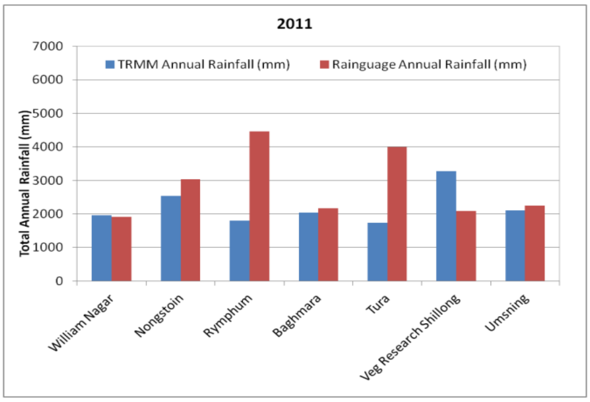
A high variability in rainfall (both TRMM and rain gauge) is apparent among the stations for each respective year in figure. The best agreement of TRMM data with rain gauge measurements was found at Rhyphum being 1.5% difference for 2013. When compared to all the years (2007 - 2016), The stations at Bhagmara, Ryphum , Jowai and William Nagar have the best agreement.

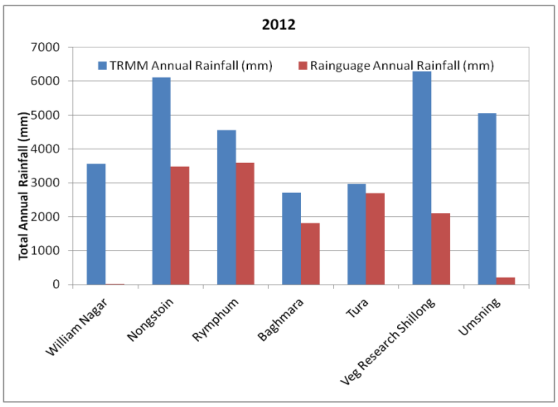












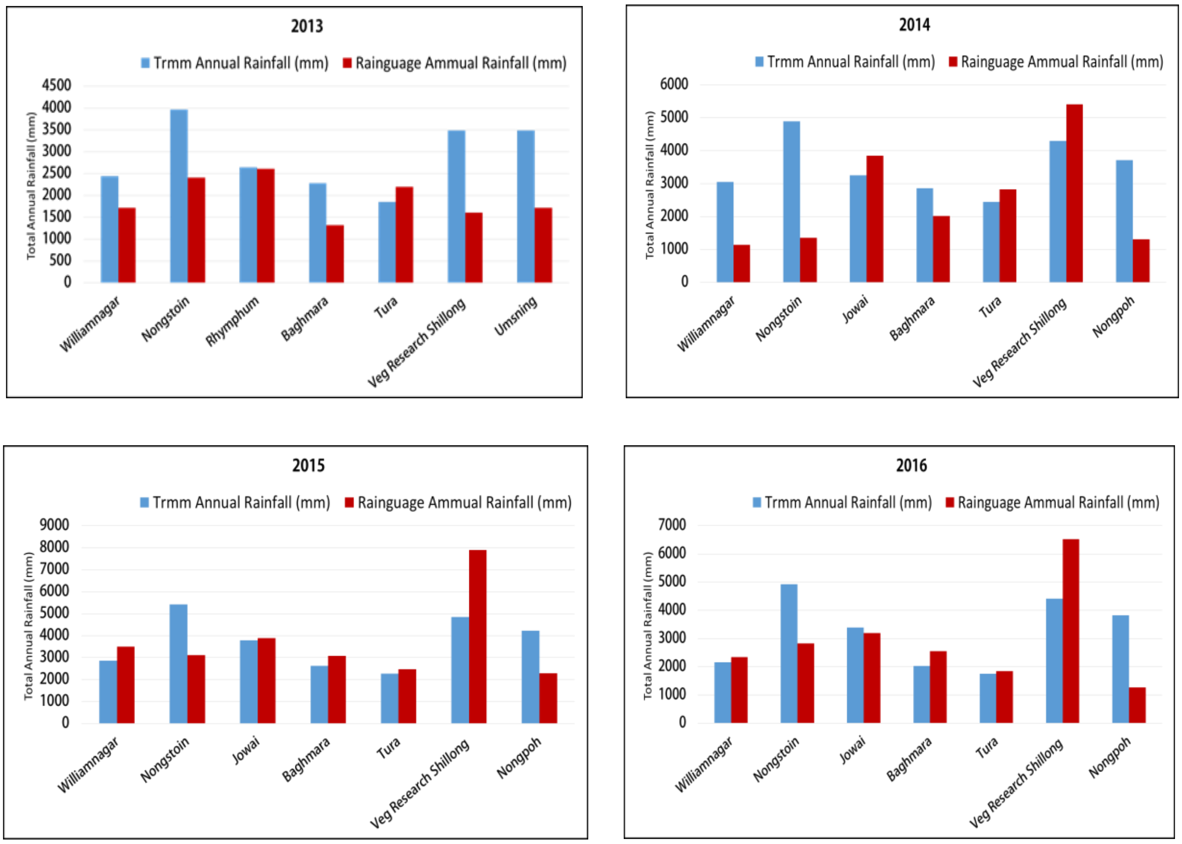


Figure 4: Annual TRMM Rainfall Comparison with Rain gauge Measurements.

5.2.2 Comparison at State Level

The comparison between TRMM and rain gauge data was also performed at the state level on monthly time step (Figure 5). In this comparison, it was apparent that typical monsoon months (July, August, and September), had the closest agreement between TRMM and rain gauge data with differences of 0%, 19%, and 2% respectively.

On annual time step, the differences between TRMM data and rain gauge measurements varied between 1.0% - 92.0% across the period of analysis (2007 - 2016), with 2016 being the best year and 2012 the worst (Figure 6).

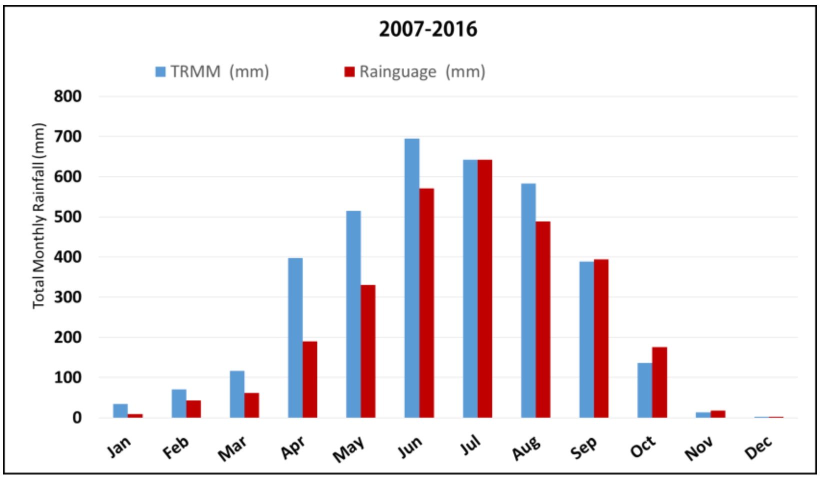


Figure 5: Distribution of Average Monthly Rainfall for Meghalaya (2007 – 2016).

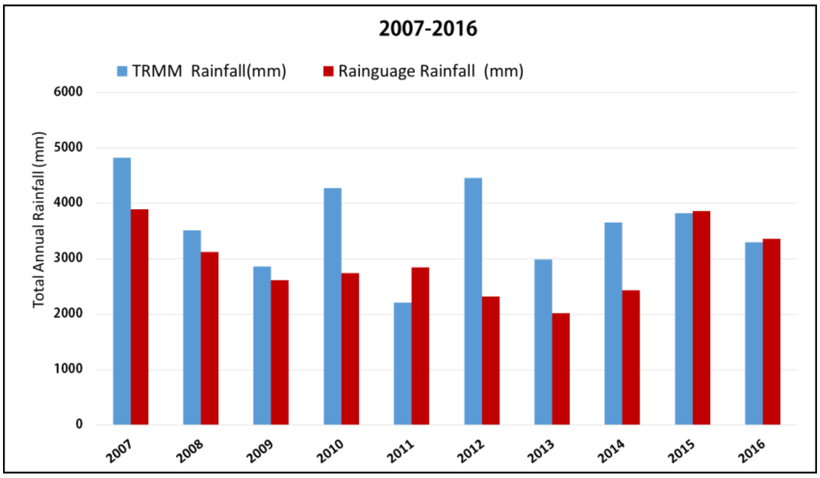


Figure 6: Distribution of Annual Rainfall For Meghalaya (2007 – 2016).

6. CONCLUSIONS

The present study was conducted to assess the spatial-temporal accuracy of remotely sensed gridded rainfall data (TRMM 3B43) for the state of Meghalaya. TRMM 3B43 grids representing monthly accumulated rainfall for the period 2008-2012 were downloaded from NASA's GIOVANNI website. Rainfall data obtained from seven Rain gauge stations spread across the state were used to assess and evaluate the TRMM 3B43 gridded data. The representative area for each Rain gauge station was delineated using Thiessen polygon method. The TRMM 3B43 rainfall data were extracted for each delineated area and compared with the respective area weighted rainfall from each rain gauge station.

The following conclusions were drawn from this study:

- At individual station level, rainfall obtained from TRMM 3B43 data for the area represented by Rhyphum station was found to be in close agreement with the concurrent rain gauge data with a difference of 1.5% at 2013. When compared across all the years (2007 - 2016), The stations at Bhagmara, Ryphum , Jowai and William Nagar have the best agreement.

- The TRMM rainfall data across the period of analysis (2007 - 2016) for Meghalaya was found in closer agreement with rain gauge data for the typical monsoon months of July, August and September with differences of 0%, 19%, and 2% respectively. The non-monsoon months, except December (0%) showed high differences, the average being 65.6%.

- Annually, the best agreement between TRMM and concurrent rain gauge data for Meghalaya was found to be in 2016 with an overall difference of 1%, the worst being 2012 (92%)

- Difference apparent between TRMM and rain gauge data can be attributed to potential errors in rainfall estimated by TRMM and/or measurements taken by the rain gauge. Differences between TRMM and rain gauge measurements can also be due to the known limitation of rain gauge station in capturing spatial variability in rainfall for which a spatial/gridded data like TRMM can be more accurate.

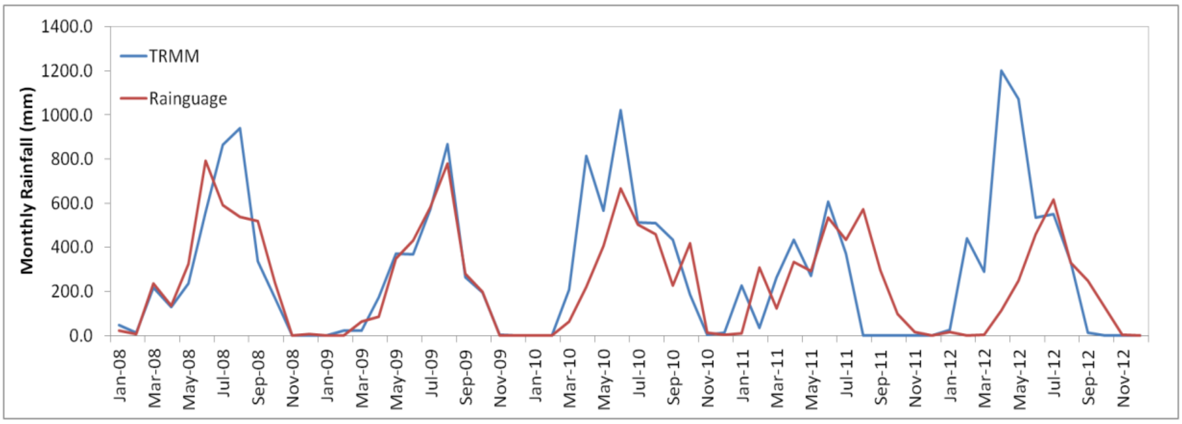


Figure 6: Monthly Rainfalls for Meghalaya during 2008 – 2012.

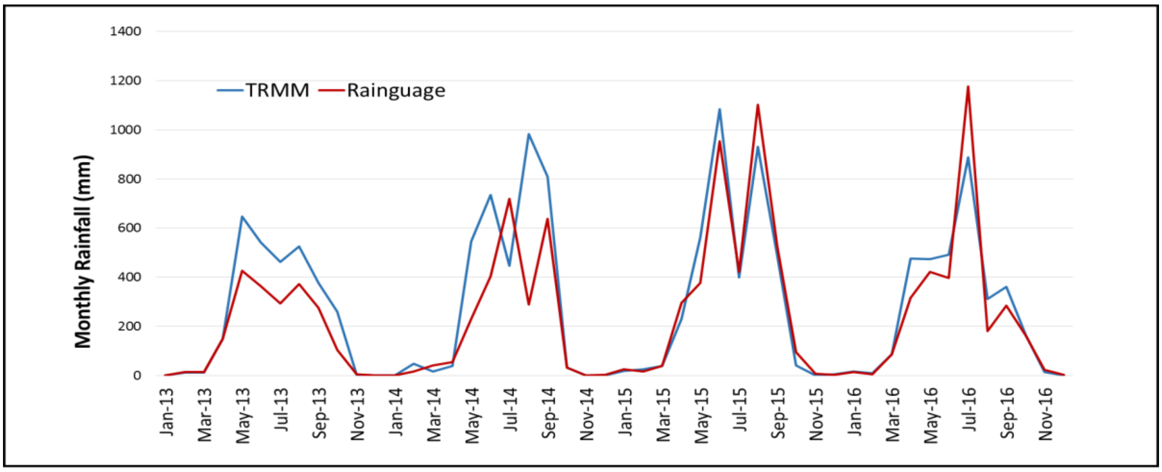


Figure 7: Monthly Rainfalls for Meghalaya during 2013 – 2016.

Overall, the TRMM data followed the trend of rainfall (highs and lows) as apparent in rain gauge data at the monthly time step for the state of Meghalaya, mostly for all the years of analysis (Figure 6 and 7). The TRMM data can be a viable option to analyze rainfall trend for Meghalaya, particularly in those areas where the density of rain gauges are not good enough to capture the spatial variation in rainfall.

6.1 Recommendations

The following recommendations are made in context to the results obtained and conclusions made for the present study:

- Different datasets of TRMM can be used to do the assessment at different temporal scales like hourly and daily basis.
- Further analysis should be conducted to investigate that why some stations are closer than others in the comparison of the TRMM data and rain gauge measurements.
- A proper Quality Check can be done on the data received by the Rain Gauge stations.
- More years should be considered when such type of an analysis is conducted in future particularly grouping the years into dry, wet and normal years. This will aid in getting more information on the bias apparent in TRMM data.

7. ACKNOWLEDGEMENT

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