# VALIDATION OF INTEGRATED MULTI-SATELLITE RETRIEVALS FOR GPM DATA IN BANGLADESH

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## ABSTRACT

*To study the possibility to use of Integrated Multi-satellitE Retrievals for GPM (IMERG) rainfall data in Bangladesh, half-hourly IMERG data of spatial resolution 0.1 degree×0.1 degree and three hourly Bangladesh Meteorological Department (BMD) rain gauge data of 35 stations are used. The study period was from April, 2014 to May, 2015. In daily scale, the Correlation Coefficient (CC) and Root Mean Square Error (RMSE) between IMERG and rain gauge data is found 0.79 and 6.19, respectively. The IMERG and BMD observed daily average rainfall is found 4.18mm and 5.61mm during the study period, respectively. IMERG is able to measure 74.5% of the surface rainfall in Bangladesh during the study period. In monthly and seasonal scale, the IMERG data is highly correlated with BMD observation. The IMERG rainfall is overestimated by 7.93% (29.35mm) and 12.09% (3.36mm) during the pre-monsoon and winter seasons, respectively. On the other hand, IMERG rainfall is underestimated by 37.58% (629.33mm) and 3.54% (2.65mm) during the monsoon and post-monsoon seasons, respectively. The yearly underestimation of IMERG data was 27.9%. IMERG and BMD data detect 45.40 and 40.74 light rainfall (≥2.5 to <10.5mm) events, and 1.54 and 3.51 very heavy rainfall (>88mm) events during the study period, respectively. IMERG is able to detect light rainfall more precisely than the very heavy rainfall. IMERG and BMD data detect 319 and 311 extreme low (10th percentile) rainfall events, and 8 and 12 extreme high (90th percentile) rainfall events during the study period, respectively. Further studies are necessary to explore the potential of GPM-era IMERG data for meteorological, and hydrological research in Bangladesh.*

**Keywords:** *Rainfall, Global Precipitation Measurement, Bangladesh, Correlation Coefficient, Rainfall event.*

## 1. INTRODUCTION

The primary source of water for agricultural production over most of the world is rainfall (Subash and Gangwar, 2014). The characteristics of rainfall vary from place to place, day to day, month to month and also year to year. Precise knowledge of these characteristics is essential for its proper utilization. So, rainfall variation measurement is important but, rainfall is one of the most difficult parameters to measure because of the large variations with respect to space and time (Kummerow et al., 2000). In Bangladesh, only 35 rain gauge stations data are represent the rainfall throughout the country, which is insufficient for meteorological and hydrological study. Inadequate rain gauge networks throughout the country sometimes provide incomplete information about the distribution of rainfall (Islam and Uyeda, 2005). To overcome this problem satellite observation may play an important role for the country. Satellite remote sensing is recognized as a powerful and essential means for monitoring global change of earth environment (Islam and Islam, 2006). Following the highly successful TRMM mission, NASA and JAXA designed an international project Global Precipitation Measurement (GPM) mission launched at 27 February, 2014 to provide improved estimates of precipitation over most of the globe (Huffman et al., 2015a, b). GPM carrying both a dual frequency radar instrument and a passive microwave radiometer, the core spacecraft serves as a calibration standard for the other members of the GPM spacecraft constellation. GPM is the first satellite that has been designed to measure light rain and snowfall, in addition to heavy tropical rainfall. In this paper validation of Integrated Multi-satellitE Retrievals for GPM (IMERG) data in Bangladesh is studied using rain gauge data from Bangladesh Meteorological Department (BMD).

## 2. DATA AND METHODOLOGY

### 2.1 IMERG Product

IMERG is the unified US algorithm that provides multi-satellite precipitation product. The precipitation estimates from the various precipitation-relevant satellite passive microwave sensors comprising the GPM constellation using the Goddard Profiling Algorithm (GPROF), then gridded, inter-calibrated to the GPM combined instrument product, and combined into half-hourly 0.1° × 0.1° fields. IMERG data products provide global high spatial and temporal resolution precipitation data. The data are archived in HDF5 (Hierarchical Data Format, latest version) format available from the NASA Goddard Earth Sciences Data and Information Services Centre (GES DISC). The GPM constellation of satellites can observe precipitation over the entire globe every 2-3 hours. The detailed IMERG estimation procedure is described at the **https://pmm.nasa.gov/sites/default/files/document_files/IMERG_doc.pdf**. In this study, IMERG half-hourly rainfall data from April, 2014-May, 2015 is be used for the validation of GPM data in Bangladesh.

### 2.2 Rain Gauge Data

Rain gauge is a meteorological instrument for determining the depth of precipitation (usually in mm) that occurs over a unit area (usually one metre squared) and thus measuring rainfall amount. BMD used recording type rain gauge. BMD has 35 rain-gauge stations all over the country. The locations of these 35 rain gauges are shown in Fig.1. In the current study, 3 hourly rain gauge data collected by BMD are utilized.

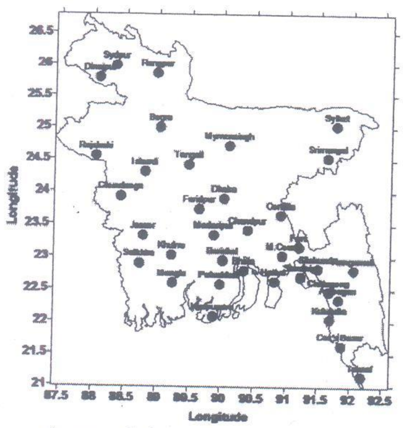

Figure 1: Locations of the rain-gauge stations of BMD.

### 2.3 Method

Grid Analysis and Display System (GrADS) script was used to extract point data from GPM global data at different BMD rain gauge station locations. In this study surfer was also used to plot spatial distribution of IMERG and BMD rainfall data. The daily, monthly and yearly rainfall is calculated from the half hourly data. In this study the Correlation Coefficient (CC), Root Mean Square Error (RMSE) and Standard deviation (SD) are also calculated. Different thresholds rainfall events are also calculated from the IMERG and rain gauge data.
There are different thresholds rainfalls according to BMD (Mannan et al., 2015) given below:

- Very heavy rainfall (VHR) is defined as the occurrence of rainfall amount greater than 88 mm in 24 hours.
- Heavy rainfall (HR) is defined as the occurrence of rainfall amount from ≥43.5 to 88 mm in 24 hours.
- Moderately heavy rainfall (MHR) is defined as the occurrence of rainfall amount from ≥22.5 to <43.5 mm in 24 hours.
- Moderate rainfall (MR) is defined as the occurrence of rainfall amount from ≥10.5 to <22.5 mm in 24 hours.
- Light rainfall (LR) is defined as the occurrence of rainfall amount from ≥2.5 to <10.5 mm in 24 hours.

In this study, it is found that the 10$^{th}$, 90$^{th}$, 95$^{th}$ and 99$^{th}$ percentiles of rainfall amount were 1.8, 48, 70 and 122 mm/day, respectively.

## 3. RESULTS AND DISCUSSION

### 3.1 Daily Rainfall Variation

Figure 2 showed the variation of daily average rainfall measured by IMERG and rain gauge during June, 2014- May, 2015.

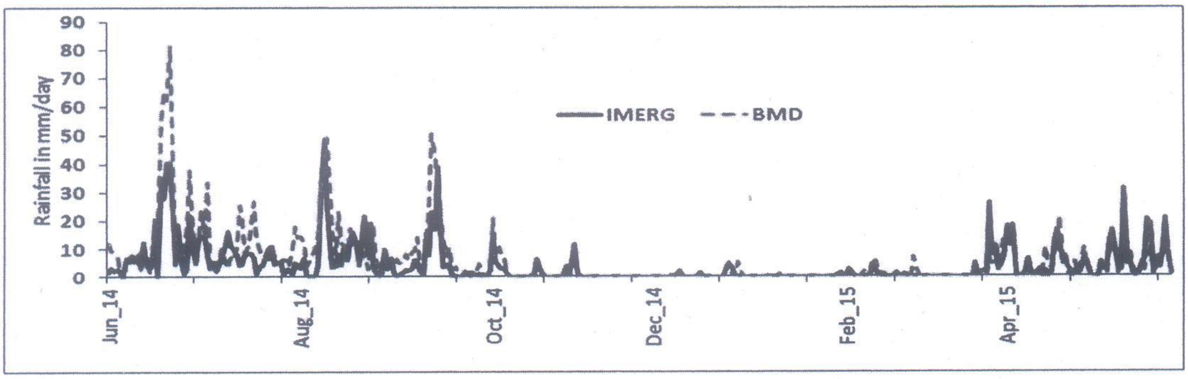


Figure 2: Variation of daily average rainfall from June, 2014 to May, 2015 over Bangladesh measured by IMERG and rain gauge.

From the above figure, it is found that the variation of daily average rainfall measured by IMERG and rain gauge are almost same. IMERG detected peaks of rainfall variations but amount was less than that of rain gauge, especially during monsoon period. The CC and RMSE is found 0.79 and 6.19 respectively. The standard deviation of IMERG and BMD is found 7.04 and 9.86, respectively. The IMERG and rain gauge measured 5.61 and 4.18mm of rainfall per day, respectively. Therefore, IMERG is able to measure 74.5% of the surface rain in Bangladesh.

### 3.2 Monthly Rainfall Variation

Figure 3 showed the IMERG and BMD rain gauge observed monthly variation of rainfall during the study period. The trend of monthly variation of IMERG and rain gauge data are almost same. The monthly CC and RMSE between IMERG and BMD is found 0.96 and 88.19, respectively. It is found that the IMERG and rain gauge data are highly co-related. The standard deviation of IMERG and BMD is 113.83 and 183.21, respectively.

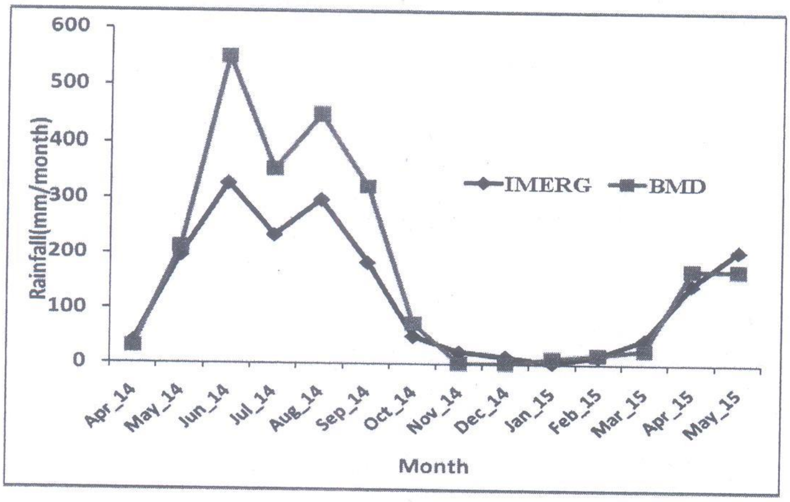


Figure 3: Monthly variation of rainfall measured by IMERG and BMD rain gauge.

From this figure it is clear that IMERG is mainly underestimated during June – September.

### 3.3 Seasonal Rainfall Variation

Figure 4 showed the seasonal variation of rainfall measured by IMERG and rain gauge during study period.

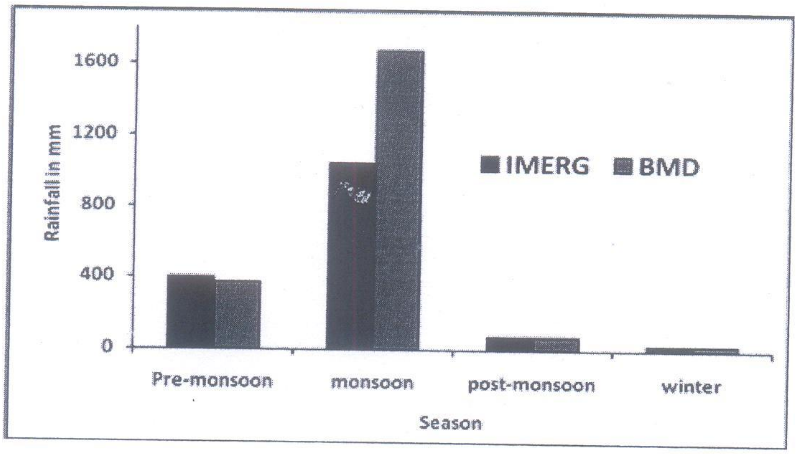


Figure 4: Seasonal variation of rainfall from June, 2014 to May, 2015 measured by IMERG and rain gauge.

From this figure it is found that the IMERG rainfall is overestimated by 7.93% (29.35mm) and 12.09% (3.36mm) during the pre-monsoon and winter seasons, respectively. On the other hand, IMERG rainfall is underestimated by 37.58% (629.33mm) and 3.54% (2.65mm) during the monsoon and post-monsoon seasons, respectively. These seasonal underestimation and overestimation may be due to the variation of vertical cross section of convection observed by IMERG. Islam and Uyeda (2008) showed that pre-monsoon convection activities are mainly observed over land, whereas monsoon and post-monsoon activities are distributed over the Bay of Bengal and land. They also showed that pre-monsoon rainfall is more intense than that during other rainy periods. The echo top height is high in pre-monsoon than in other periods. IMERG may successfully detect the tall convection during the pre-monsoon period, on the other hand it unable to detect properly the low level shallow convection during the monsoon period. The CC and RMSE between IMERG and BMD data is found 0.99 and 315.02 respectively.

### 3.4 Spatial Distribution of Annual Rainfall

Figure 5 showed the spatial distribution of annual rainfall measured by (a) IMERG and (b) BMD during June, 2014 to May, 2015. Spatial pattern showed that amount of rainfall increases from western part to eastern part of the country. From this figure it is clear that the western part of the country received less rainfall than that of northeastern and southeastern parts.

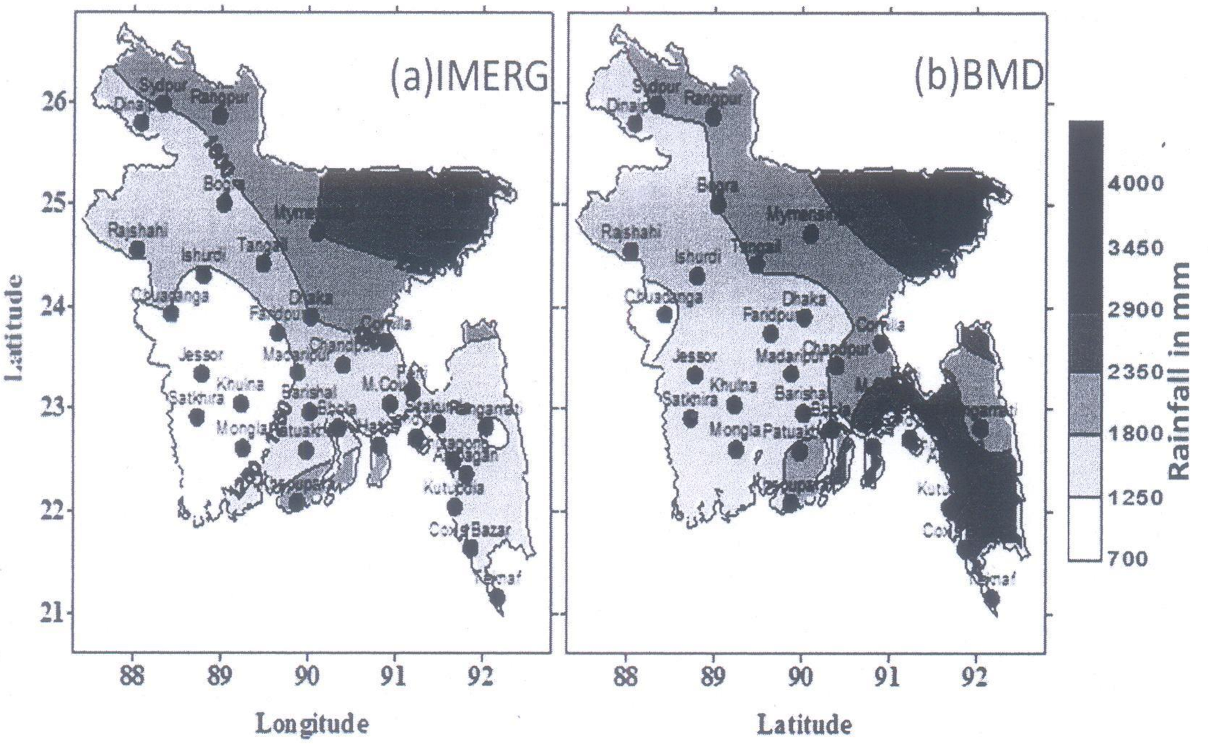


Figure 5: Spatial distribution of annual rainfall measured by (a) IMERG (b) BMD

The Meghalaya and Assam hill are situated in the northeastern part of the country, which helps for the development of convective in this area of the country. The annual rainfall measured by the IMERG and rain gauge are found 1548.366 mm and 2147.64 mm, respectively. The highest amount of rainfall measured by IMERG and rain gauge was 2645.42 mm (Sylhet) and 3989.10 mm (Sylhet), respectively. The lowest amount of rainfall measured by IMERG and rain gauge was 698.34 mm (Satkhira), and 1188.60mm (Chuadanga), respectively.

### 3.5 Anomaly of Annual Rainfall

Anomalies between IMERG and rain gauge measured rainfall is shown in figure 6. IMERG overestimated in the central and northwestern parts of the country whereas underestimated in the remaining area of the country. The yearly underestimation of IMERG data was 27.9%. The maximum underestimation and overestimation is found in Teknaf and Dhaka region, respectively.

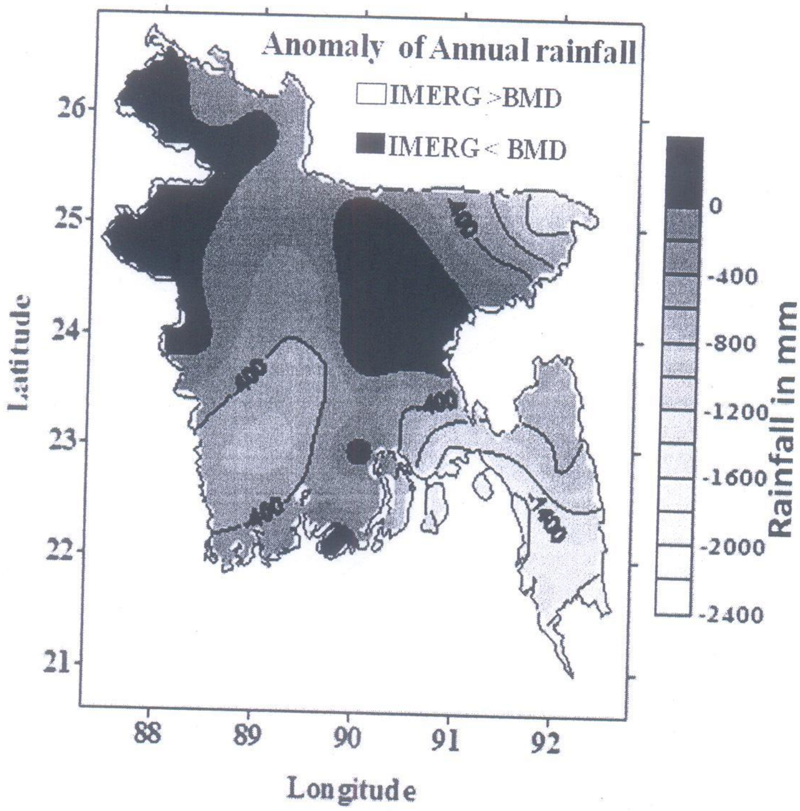


Figure 6: Anomaly of annual rainfall

### 3.6 Rainfall Events

Figure 7(a) showed the threshold rainfall events measured by IMERG and BMD and figure 7(b) showed the different percentiles of rainfall events measured by IMERG and BMD.

Number of VHR, HR, MHR, MR and LR events measured by IMERG during the study period is 1.54, 8.49, 14.63, 23.23 and 45.40, respectively. On the other hand the number of VHR, HR, MHR, MR and LR events measured by BMD rain gauge is 3.51, 10.74, 19.46, 26.29 and 40.74, respectively.Therefore it is concluded that IMERG can detect light rainfall with more precision. IMERG overestimated for 10th percentile rainfall events on the other hand underestimated for other percentiles of rainfall events (Figure 7b). From the figure 7(b) it is also found that IMERG and BMD data detect 319 and 311 extreme low (10th percentile) rainfall events, and 8 and 12 extreme high (90th percentile) rainfall events during the study period, respectively It is also found that IMERG successfully detect extreme low rainfall events more accurately.

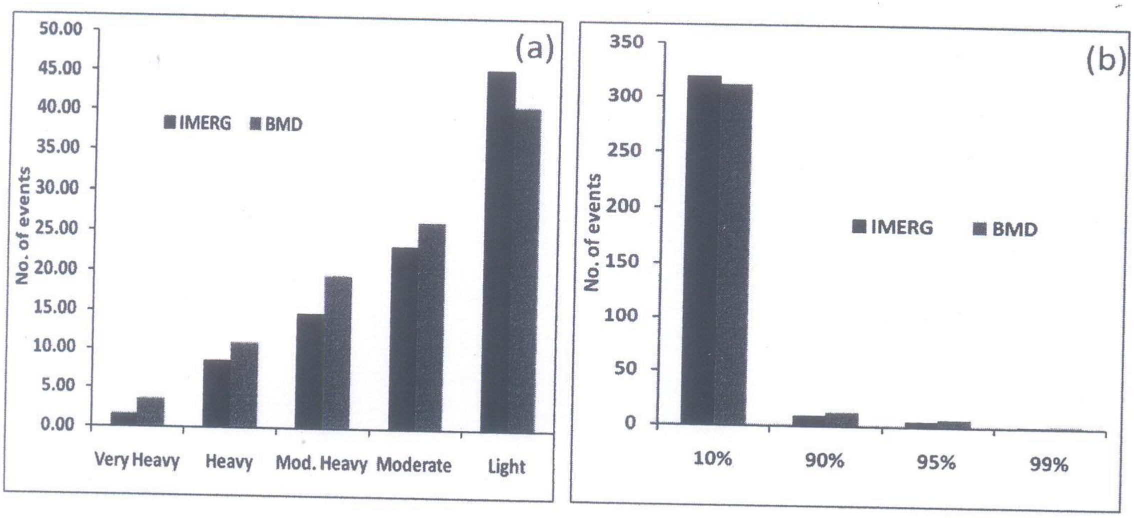


Figure.7: (a)Threshold rainfall events measured by IMERG and BMD. (b) Percentile of rainfall events measured by IMERG and BMD

## 4. CONCLUSIONS

The IMERG data and BMD rain gauge rainfall data are compared during April, 2014 to May, 2015 to validate IMERG data in Bangladesh. The CC of daily, monthly and seasonal rainfall between IMERG and rain gauge data was found 0.79, 0.96 and 0.99, respectively. In monthly and seasonal scale, the IMERG data is highly correlated with BMD observation. Based on correlation coefficient daily, monthly, seasonally IMERG data are useable for meteorological study although there are some underestimation. The IMERG are able to detect light rainfall (($\geq$2.5 to <10.5mm) and extreme rainfall (10th percentile) more precisely. Based on this priliminary analysis IMERG data may be used in Bangladesh for meteorological and hydrological study but longer range of data analysis are needed for a more comprehensive assessment of IMERG data.


## ACKNOWLEDGEMENTS

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