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COMPARISON OF TRMM TMPA RAINFALL DATASET WITH GAUGE RAINFALL DATASET OVER NORTH EAST INDIA AND NEARBY REGIONS

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ABSTRACT

In the present work tropical rainfall measuring mission (TRMM) multi satellite precipitation analysis (TMPA) rainfall dataset is compared with rain gauge dataset of Global Precipitation Climatology Centre (GPCC) over land comprising of different topography over North East India and nearby regions in monthly scale for the period 1998 to 2010. The region selected for the study is within latitude interval 22.5^{0}N-27.5 ^{0}N and longitude interval 90^{0}E-97.5^{0}E which includes North East India, parts of Bhutan, Bangladesh and Myanmar. The considered region is initially divided into six sub regions-R-I (25^{0}N-27.5^{0}N, 90^{0}E-92.5^{0}E), R-II (25^{0}N-27.5^{0}N, 92.5^{0}E-95^{0}E), R-III (25^{0}N-27.5^{0}N, 95^{0}E-97.5^{0}E), R-IV (22.5^{0}N-25^{0}N, 90^{0}E-92.5^{0}E), R-V (22.5^{0}N-25^{0}N, 92.5^{0}E-95^{0}E) and R-VI (22.5^{0}N-25^{0}N, 95^{0}E-97.5^{0}E). Monthly TMPA rainfall dataset 3B43 Version 7 (TRMM 3B43-V7) is compared with rain gauge measured rainfall GPCC-Version 6 (V6) over all the six sub regions in terms of correlation coefficient (CC), bias and root mean square error (RMSE). For all the regions CC shows very high value indicating very good correspondence between the two dataset. But bias and RMSE are quite different for different regions. For sub regions R-I and R-VI there is positive bias of 3B43-V7 rainfall data and for region R-I the positive bias is highest. For the other regions there is negative bias. The highest positive bias of region R-I is analyzed in detail by considering three locations (a) 27.25^{0}N, 91.75^{0}E -located inside Bhutan (L-I) (b) 26.75^{0}N, 91.75^{0}E located in Lower Assam (L-II) (c) 25.75^{0}N, 91.75^{0}E , located in Meghalaya (L-III). From the analysis it is found that for the considered location of Meghalaya (L-III) the bias is positive and is of very high value indicating that satellite over estimates the rainfall in maximum extent over Meghalaya (hilly and high rainfall region) than the actual rainfall. At the other two locations i.e. Lower Assam (L-II) and Bhutan (L-I), satellite under-estimates the rainfall. It is also found that this positive bias arises mainly due to over estimation of rainfall by the satellite in the month of June, July and August.

KEYWORDS: TRMM, TMPA, 3B43-V6, 3B43-V7, GPCC-V6

INTRODUCTION:

Rainfall is the most important parameter in hydrological cycle and knowledge of rainfall pattern over a region is important for agricultural planning and production. Rainfall variation may initiate natural disaster such as flood-drought-landslide etc. and also knowledge of rainfall is important for water budget. The rainfall measurement by rain gauge is the oldest but most accurate technique. Over land, rainfall is extensively measured using rain gauge and over ocean also rainfall can be measured by rain gauge using buoy platform. But as the rain gauge rainfall measurement is a point measurement and it is not available everywhere, so rainfall measurement by rain gauges are supplemented by radar [1-3] and satellite [4-10].

Global gridded rainfall dataset from rain gauge is one of the most important dataset not only for operational purpose but also important for research in the field of climatology, meteorology, atmospheric science etc. One of such dataset is Global Precipitation Climatology Centre (GPCC) dataset [11]. The full data product (V6) of GPCC is the most accurate in situ precipitation data set. The full data product (V6) is available for the period 1901 to 2010 in monthly time scale. This data set is prepared by interpolation of rain gauge data at uniform spatial resolution. The data set is available in regular gridded spatial resolutions of 0.5^0 x 0.5^0, 1^0x1^0 and 2.5^0x2.5^0. This dataset can be used for regional climate monitoring, climate variability and water resource assessment studies.

Tropical rainfall measuring mission (TRMM) precipitation dataset is a widely used precipitation data. TRMM mission is joint effort of US and Japan to measure tropical precipitation. TRMM satellite was launched in 1997 to study precipitation over tropical region [12]. The satellite's active and passive sensors could provide radar reflectivity profiles and high resolution passive microwave measurements. The sensors of TRMM satellite that are important for precipitation measurement are precipitation radar (PR), TRMM microwave imager (TMI) and visible and infrared scanner (VIRS). The tropical rainfall measuring mission (TRMM) multi satellite precipitation analysis (TMPA) dataset is merged precipitation dataset of many satellites along with gauge analysis [13]. The TMPA dataset preparation steps are [13]:

a) Microwave precipitation data set of passive microwave sensors of different satellites (Tropical rainfall measuring mission (TRMM) satellite, Defense Meteorological satellite Program (DMSP) satellites, Aqua and National Oceanic and Atmospheric Administration (NOAA) satellites) are combined and calibrated.
b) The infrared (IR) precipitation of different geosynchronous satellites is created.

c) The microwave and IR precipitation products are combined.

d) Rain gauge data is incorporated with combined microwave and IR products.

TMPA data is available for both real time and after real time and with after real time data only rain gauge data is incorporated. 3B42RT is the merged microwave and IR real time daily gridded rainfall dataset and 3B42- V6 is the merged microwave and IR post real time daily gridded rainfall dataset after incorporation of rain gauge data. 3B43-V6 is post real time monthly data with incorporation of gauge data with combined microwave and IR products [13]. 3B43-V7 is the latest version of 3B43 introduced in May 2012 which supersedes all the previous versions. Routine production of TRMM satellite precipitation radar (PR) data has been stopped in October 2014 and TRMM microwave radiometer (TMI) data production has been stopped in the spring season of the year 2015 due to decommissioning of TRMM satellite. TMPA-research version products 3B42 and 3B43 data production by the previous method have been stopped from September 2014. But the production of 3B42 and 3B43 dataset with climatologically adjusted methods has been started since October 2014[14, 15].

Many researchers have compared different rainfall dataset at different regions of the globe with different targets and results [16, 17, 18 and19, 20]. It is already documented that almost all the presently available rainfall dataset have difficulties in representing the rainfall over Western Ghats, North East India and foothills of Himalaya [21]. As TMPA product 3B43 V-7 data set incorporates rain gauge data (Until March 2005, GPCC rain gauge data and from April 2005 Climate Assessment and Monitoring system (CAMS) rain gauge data) [13], it can be assumed that there should be minimum difference between these two datasets. The present work is aimed to study the differences between rainfall data of 3B43-V7 and GPCC full data product (V6) over North East India and nearby regions.

STUDY REGIONS:

The region selected for the study is within latitude interval 22.5^0N-27.5N and longitude interval 90^0E-97.5^0E (Fig-1). The considered region is initially divided into the following six sub regions (Figure-1).

R-I (25^0N-27.5^0N, 90^0E-92.5^0E)-Part of Bhutan, Lower Assam and Meghalaya.

R-II (25^0N-27.5^0N, 92.5^0E-95^0E)-Part of Arunachal Pradesh, Middle and Upper Assam, part of Nagaland and Manipur.

R-III (25^0N-27.5^0N, 95^0E-97.5^0E)-Part of Eastern Assam, Nagaland and Myanmar

R-IV (22.5^0N-25^0N, 90^0E-92.5^0E)-Mainly Tripura, Part of Southern Assam, Sylhet and Sitagong division of Bangladesh up to Bay of Bengal.

R-V (22.5^0N-25^0N, 92.5^0E-95^0E)-Part of Southern Assam, Part of Manipur and Part of Mizoram and Myanmar.

R-VI (22.5^0N-25^0N, 95^0E-97.5^0E)-Part of Myanmar only.

MATERIALS AND METHODS:

For all these six sub regions, monthly 3B43-V7 rainfall dataset of TMPA have been downloaded from Giovanni portal of NASA for the period January 1998 to December 2010. Monthly rainfall dataset of GPCC (full data product -V6) have been downloaded from NOAA website at different grid points and by averaging the monthly rainfall have been calculated for all the above mentioned six sub regions for the same period. The two dataset have been compared for all the six sub regions in terms of correlation coefficient (CC), bias and root mean square error (RMSE) using the relations

$$Correlation\,Coefficient, cc = \frac{\sum_{i=1}^{n}(S_i - \bar{S})(G_i - \bar{G})}{n\sqrt{\sum_{i=1}^{n}(S_i - \bar{S})^2 \sum_{i=1}^{n}(G_i - \bar{G})^2}}$$

$$Bias = \frac{1}{n}\sum_{i=1}^{n}(S_i - G_i)$$

$$Root\,Mean\,Square\,Error\;\;(RMSE) = \sqrt{\left(\frac{1}{n}\sum_{i=1}^{n}(S_i - G_i)^2\right)}$$

Here S_i is the 3B43-V7 rainfall, G_i is the GPCC rainfall, $\bar{S}$ and $\bar{G}$ are their arithmetic mean and n is the number of data points. It is seen that bias of 3B43-V7 rainfall data is highly positive for the region R-I (Table-1). To analyze the monthly rainfall in sub region R-I in a more detailed manner, three locations have been selected within that sub region. The locations (Fig-1) are given below-

L-I (27.25^0N, 91.75^0E)-Located inside Bhutan

L-II (26.750N, 91.75^0E)-Located in Lower Assam

L-III (25.75^0N, 91.75^0E) - Located in Meghalaya

At these locations also monthly rainfall have been compared.

RESULT AND DISCUSSION:

Comparison of the rainfall products 3B43 V-7 and GPCC V-6 is shown in Table-1. It is seen that for all the regions, the correlation coefficients (CC) have very high values and they are

0.99, 0.99, 0.99, 0.99, 0.98 and 0.97 for sub regions R-I, R-II, R-III, R-IV, R-V and R-VI respectively.

For combined region (R-I to R-VI) the CC is 0.99 and it indicates that both the data set corresponds to each other in maximum extent over all the sub regions.

But bias of 3B43 V-7 dataset is different for different regions over GPCC dataset (Table-1). The bias is positive for regions R-I and R-VI whereas bias is negative for other regions. The bias is positive in highest extent over region R-I (Table-1). It exhibits that satellite and rain gauge merged dataset of TMPA (3B43 V-7) over-estimates the rainfall over gauge estimation over regions R-I and R-VI and for other regions it under-estimates the same. But as 3B43 V-7 incorporates gauge data, it is expected to have very low difference between 3B43 V-7 and GPCC V-6 data set and the nature of differences is expected to be identical for all the regions.

The more detailed analysis of region R-I with three locations L-I (Bhutan), L-II (Lower Assam) and L-III (Meghalaya) is given in Table-2. At locations L-I, L-II and L-III the CC between considered dataset is very high which confirms the high correspondence between the two dataset over all the three locations of region R-I. The bias of 3B43 V-7 over gauge estimation is negative for locations L-I and L-II, but bias is highly positive for location L-III (Meghalaya) (Table-2). To find the months for which highest rainfall difference arises, the total accumulated rainfall over the location L-I is calculated both from 3B43-V7 and GPCC for the period 1998 to 2010 and rainfall difference per month is calculated considering all months, June to September, June to August, May to August and May to September. It is seen that this high positive bias over location L-III i.e. over Meghalaya is due to over estimation of very heavy rainfall by the satellite mainly for the months of June, July and August (Fig 2, Table-3).

CONCLUSION:

It is seen that from region to region the bias of 3B43-V7 rainfall data are different in comparison to gauge data of GPCC (though gauge data is incorporated with 3B43 dataset). This is due to uncertainties of satellite as well gauge measurements. But as gauge measurements are direct ones, they are assumed to be better than other measurements. But the production of gridded gauge data such as GPCC data is involved with different mathematical procedures which may bring some uncertainties. But more uncertainties may be with the satellite measurements which involves indirect rainfall measurements. From the analysis it is seen that uncertainties of rainfall measurement is more over hilly high rain region of North East India. From the analysis it can be concluded that all the satellite based rainfall data should be bias corrected in regional scale for better performance.

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TABLES AND FIGURES:

Table-1 CC, bias and RMSE for the different sub regions.

REGION	CC	bias(mm)	RMSE(mm)
25N-27.5N,90E-92.5E(R-I)	0.99	26.58	38.8
25N-27.5N,92.5E-95E(R-II)	0.99	-10.54	23.46
25N-27.5N,95E-97.5E(R-III)	0.99	-12.41	43.24
22.5N-25N,90E-92.5E(R-IV)	0.99	-5.96	27.37
22.5N-25N,92.5E-95E(R-V)	0.98	-1.98	24.98
22.5N-25N,95E-97.5E(R-VI)	0.97	25.17	42.54
22.5N-27.5N,90E-97.5E	0.99	3.24	10.13

Table-2 CC, bias and RMSE for the different locations of sub region R-I

LOCATIONS	CC	bias(mm)	RMSE(mm)
(27.25N,91.75E)-L-I (Bhutan)	0.98	-6.44	29.07
(26.75N,91.75E)-L-II (Lower Assam)	0.98	-27.22	61.29
(25.75N,91.75E)-L-III (Meghalaya)	0.96	210.05	326.18

Table-3 Accumulated rainfall over the location L-III (Meghalaya)

PERIOD	3B43(mm)	GPCC(mm)	DIFFERENCE (mm)	DIFFERENCE PER MONTH(mm)
ALL MONTHS	72753.74	39985.6	32768.14	210.05
MAY to SEPT	60358.29	30943.1	29415.19	452.54
MAY to AUG	53826.81	27334.9	26491.91	509.44
JUNE to SEPT	52179.23	26583	25596.23	492.23
JUNE to AUG	45647.75	22974.8	22672.95	581.33

Figure 1: Study region and sub regions (From Google Earth)

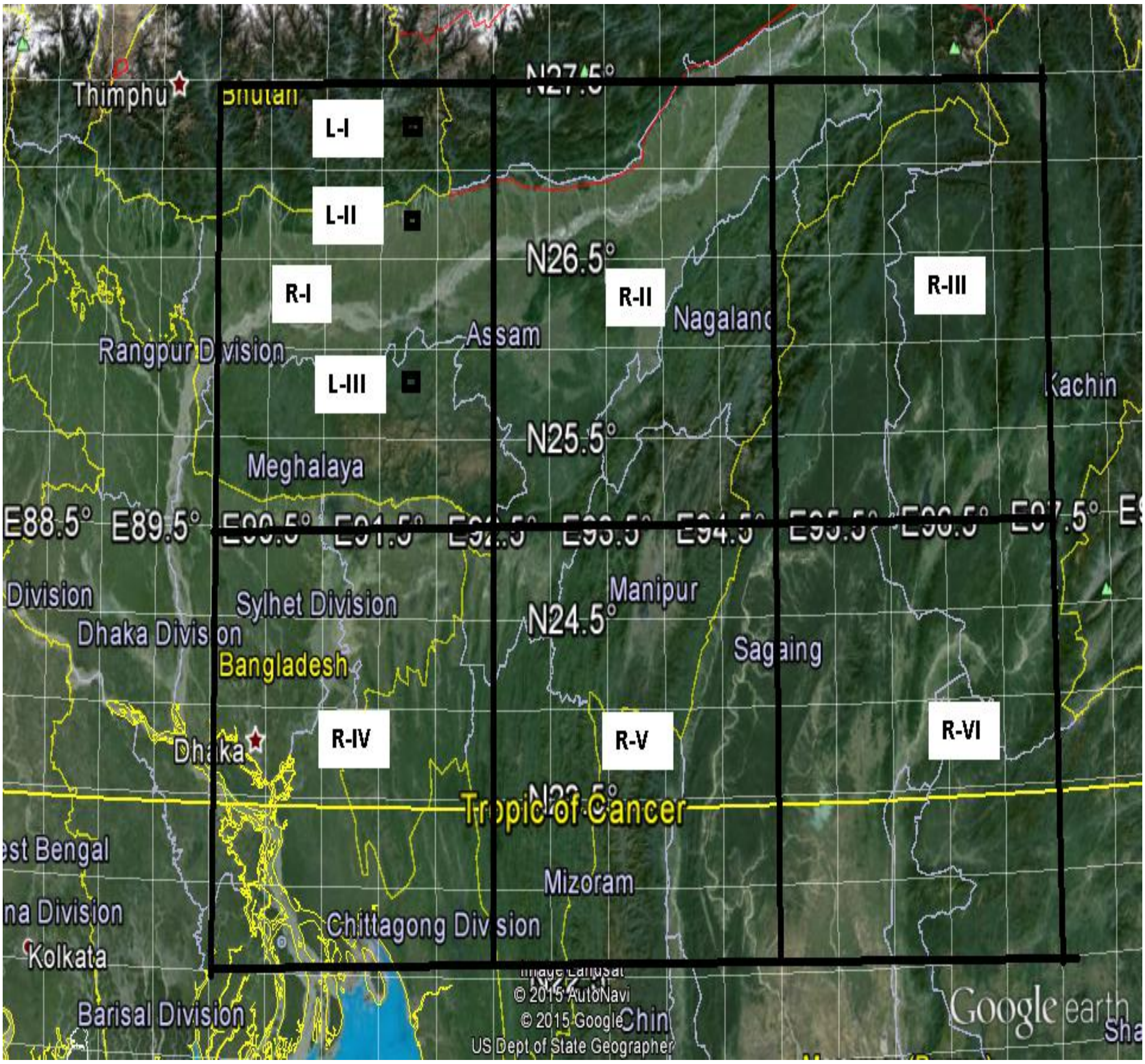

Figure 2: Monthly rainfall plot over different locations of sub region R-I.